Building Infrastructure to Enhance Integration of Research and Education

Beth Montelone

Associate Dean of the College of Arts and Sciences, Kansas State University
Interim Research Director, Biosecurity Research Institute

One way to sustain and enhance the research mission of a public university is to link it to other components of the overall mission of that institution. For example, public universities in general are expected to serve an instructional role, particularly at the undergraduate level. Those institutions designated as land grants have an additional component to their charge that includes education in the practical fields, as well as extension and outreach to the people of their state. If research and scholarly activity can be coupled to the instructional or land grant aspects of the institution, it helps to illustrate the value of research to all components of the overall mission. Federal funding agencies such as the National Science Foundation (NSF) have long made this type of linkage overt, in their focus on the broader impacts of any funded research project as an important criterion for merit review.[1]

Buzz Words in Research and Funding

A perusal of grant solicitations reveals some words and phrases currently in vogue that suggest the directions in which funding agencies think that the research enterprise should be heading. Among these are:

- Collaboration
- Innovation
- Integration
- Interdisciplinary/multi-disciplinary
- Assessment/evaluation

The current extramural funding situation for standard single-investigator projects and larger overarching efforts is complex. The recent Federal stimulus program delivered through the American Recovery and Reinvestment Act provided a strong "bump" in funding levels, especially from NIH and NSF, but there is concern that there will now be a corresponding dip next year. This is particularly true for NIH-funded challenge grants, all of which expire after two years.[2] It also is not clear to what extent the stimulus increased innovation in science; as the short- and long-term impact on innovation of Federal science investment in general is difficult to assess.[3]

Data suggest that interdisciplinary research approaches bring with them both challenges and benefits.[4] As a National Academies panel begins to

examine how to make research universities more effective,[5] an editorial in *Science* urges fostering the careers of young scientists through more collaboration, cross-disciplinary efforts, and integration of research and education.[6]

Challenges to developing truly inter- or multi-disciplinary collaborative research efforts at Kansas State University (K-State) include its traditionally decentralized culture, which vests extensive power in departments, as well as regulations of the Kansas Board of Regents regarding student enrollment minima for graduate programs. These were among the barriers to collaborative and interdisciplinary research initiatives identified by a recent K-State Presidential Research Infrastructure Task Force.[7]

Nonetheless, some progress has been made in recent years at K-State toward the national trends promoting collaboration and interdisciplinary work. These include an internally funded research support program as well as other programmatic efforts to link isolated education and outreach efforts and provide central resources to facilitate linking research and education.

Targeted Excellence and Other Collaborative Activities

The K-State Targeted Excellence (TE) program solicited proposals during five evaluation cycles from 2003-04 through 2007-08. This program was funded from tuition monies and managed jointly by the K-State Provost's Office and Vice President for Research Office. It was intended to "enhance those programs (primarily inter-disciplinary) with the most promise of elevating the university's stature."[8]

The program considered cross-departmental projects that involved multi-disciplinary themes or ideas, projects that varied in duration from a minimum of one to a maximum of five years, and requests from $50,000 to $2,000,000. A total of 29 distinct projects was funded over the lifetime of the program; some represented relatively small investments to initiate projects (ca. $100,000), while others were large collaborative awards of $2M over multiple years. These major awards established new research centers and institutes, made seed funding available to stimulate innovative and collaborative research, and provided an important university resource for encouragement, support, and mentoring of junior faculty members. Some of these centers are described below.

- The *Ecological Genomics Institute* brought together scientists using cellular and molecular biological approaches with those interested in ecological and evolutionary questions to create new cutting edge research and synergize interactions across colleges and departments. Part of their funding was used as start-up for hiring two new faculty members and supported initial research projects by other individuals and teams.
- The *Center for Genomic Studies on Arthropods Affecting Human, Animal, and Plant Health* built on expertise of faculty members in Agriculture, Arts & Sciences, and Veterinary Medicine who work on a variety of areas including insect developmental genetics, biochemistry, animal disease, and plant disease. It built capacity in

genomics and bioinformatics through personnel hires and equipment purchases. New faculty members were supported through a seed grant mechanism and the establishment of collaborative work groups.

- The *Consortium for Global Research on Water-based Economies* (GRoWE) is a collaborative organization dedicated to helping people understand and manage the relationships between water resources and human consumption for agricultural production and livelihood. GRoWE organizes a multidisciplinary team of researchers who work together with stakeholders, agencies and policy makers of water resources to further scientific understanding of water resource systems for the purpose of making better management and policy decisions. GRoWE researchers are working on coupled model approaches (e.g. hydrologic-economic) and data standards and data models for linking models and modeling techniques (e.g. groundwater data model for ArcGIS).
- The *Center for the Understanding of Origins* is an interdisciplinary effort aimed at fostering interdisciplinary research addressing issues of origins, especially the origin of the physical universe, of the earth, of life, of intelligence, and of language. It comprises faculty members from the departments of Biology, English, Entomology, History, Geology, Philosophy, and Physics. They have developed undergraduate and graduate programs and sponsor both academic and public speakers, with the aim of transforming the discussion of important origins subjects such as evolution from one of hostile arguments between "experts" and "special interests" to informed debate among citizens.
- The *Center for Sustainable Energy*, through research and educational efforts, seeks to provide sustainable, renewable energy while maintaining the environment and providing an adequate food supply. K-State offers significant educational and scientific resources related to the complete cycle of biofuels production. Basic and applied research, education, and outreach activities are components of the center. More than 30 faculty from across campus, including the colleges of agriculture, arts and sciences, and engineering, are involved in center activities.

Some of the projects established using TE funding have subsequently been developed into major extramurally funded projects. Many of these are interdisciplinary in nature and/or include aspects of or are entirely focused on broadening participation in STEM fields or integrating research and education. For example, the establishment of the Center for Sustainable Energy provided the foundation for a successful NSF Integrative Graduate Education and Research Traineeship (IGERT) project (Integrating the Social, Technological, and Agricultural Aspects of Renewable and Sustainable Biorefining (I-STAR)) as well as an NSF Research Experiences for Undergraduates (REU) project involving undergraduates in sustainability research. Faculty members from the Ecological Genomics Institute obtained an award from the U.S. Department of Education Graduate Assistance in Areas of National Need (GAANN) program to

create graduate traineeships in ecological genomics. They also won a renewal of an established NSF REU program with a new ecological genomics focus and have recently been awarded an NSF grant for Undergraduate Research and Mentoring (URM).

Two other TE projects, the Center for the Understanding of Origins and the Center for Sensors and Sensor Development led to two distinct NSF-supported Graduate Teaching Fellows in K-12 Education (GK-12) awards: "Evidence Based Inquiry into the Distant, Remote, or Past (EIDRoP)" and "Infusing System Design and Sensor Technology in Education (INSIGHT)". Faculty members involved in the Consortium for Global Research on Water-based Economies recently received a major award from the NSF Geosciences Directorate for an interdisciplinary collaborative project entitled "Hyper-extractive economies and sustainability: scenarios for sustainable water use in the High Plains Aquifer" (0909515**)**.

Other vehicles for promoting collaboration among faculty members and across units at K-State collaboration include a nationally recognized professional development school (*K-State Professional Development Schools*, 2009) that relies on collaboration among faculty in the College of Arts & Sciences, College of Education, and twenty school districts for the ongoing preparation of teachers. The Center for Science Education, housed in the College of Education, works with outreach efforts (GROW and EXCITE) as well as a variety of researchers in STEM fields, including the two GK-12 projects, a recently funded Robert Noyce Scholarship Program, a nationally-funded 4-H curriculum on sustainability, and a recently funded EPSCoR project on climate change.

Other collaborative initiatives have emphasized linkages outside the university. The Consortium for Global Research on Water-based Economies (GRoWE) makes use of linkages with state agencies, extension and rural constituencies with regard to water usage. The recently established K-State Olathe campus acts as a test-bed for strategies that link research in animal health to education.[9] Finally the Advanced Manufacturing Institute (AMI) has received a second NSF Partnerships for innovation Grant focused on building Kansas' capacity to support technology related to the effective use of biofuels.

CORES

Targeted Excellence also funded a *Collaborative for Outreach, Recruitment, Retention, and Engagement in Science, Technology, Engineering, and Mathematics (CORES)*, which supports a variety of K-State outreach, recruitment and retention efforts in STEM disciplines. CORES links science/engineering-based K-12 outreach and undergraduate research/engagement programs, including those aimed at women and underrepresented minority students. Its goals are to synergistically enhance all of its constituent programs, facilitate recruiting and tracking of students, recruit students to K-State undergraduate and graduate programs, and to institutionalize and facilitate "broader impact" activities for K-State faculty preparing grant proposals.

CORES was developed by the interdisciplinary team that created the STEM middle school outreach program Girls Researching Our World (GROW). Members of this team were responsible for a pending proposal to the NSF Innovation through Institutional Integration (I^3) solicitation. I^3 is a cross-cutting program of the NSF Education and Human Resource (EHR) Directorate and is intended to link and enhance EHR–funded projects on a single campus. The K-State proposal builds on interdisciplinary research programs created as a result of TE and uses CORES as well as the K-State NSF ADVANCE program[10] as models. A major partner is the K-State Office of Educational Innovation and Evaluation (OEIE).[11] The PI of the K-State I^3 proposal is the Provost, April Mason. Co-PIs are Ruth Dyer, Senior Vice Provost, Jan Middendorf, Interim Director of OEIE, Beth Montelone, Associate Dean of Arts and Sciences and CORES Project Director, and Jacqueline Spears, Director of the Center for Science Education.

Pending K-State I^3 Proposal: A Vision for Linking Collaborative Interdisciplinary Research and Education

The vision articulated in the proposal was of a robust institutional infrastructure capable of supporting integration of collaborative STEM projects for the purpose of broadening participation in STEM fields. The intent was to build on existing collaborative activities, especially those that involve integrating research and education.

Kezar[12] pointed out that there is limited research on how universities move from a culture supportive of individual activity to one supportive of collaborative activity. Comparisons with a larger research base in corporate organizations suggest eight factors are important to university transformations: ". . . (1) mission; (2) integrating structures; (3) campus networks; (4) rewards; (5) a sense of priority from people in senior positions; (6) external pressure; (7) values; and (8) learning." (Kezar, 2006, p. 833). Rather than focus on moving the university as a whole toward a collaborative culture, we proposed using Kezar's research to inform efforts to integrate pockets of current STEM collaboration. The proposal focused on efforts to define a shared mission, create integrating structures, and broaden campus networks for the purpose of broadening participation in STEM fields, integrating research and education and fostering innovation.

The goals of the I^3 proposal were to:

- Establish a faculty-led infrastructure designed to integrate existing collaborative STEM projects, encourage broader uses of collaborative strategies among STEM faculty, and identify institutional or departmental barriers to collaborative work;
- Build an internal evaluation capacity to support local program assessment, the identification of best practices, and central administration prioritization;
- Build an integrated approach to recruiting and retaining STEM undergraduates that is linked to university-wide

student recruitment and retention efforts;

- Increase faculty knowledge of and involvement in integrating research and education and the development of innovative programs.

Elements of the K-State I^3 Project addressed the first three of Kezar's eight core elements. Promoting broader participation in STEM fields is a critical aspect of the university mission and offered a shared focal point around which university administrators, faculty and staff could engage. The faculty-led infrastructure proposed provided an integrating structure capable of encouraging broadened campus networks. In addition, we are in the process of using internal funding to develop an internal evaluation capacity to support the institutional learning important to continued integration and innovation. **Figure 1** provides a conceptual model that illustrates how funded projects and existing resources would be integrated as part of the I^3 project.

The project goals would be accomplished through four proposed activities.

Activity 1

We proposed establishing a faculty-led office designed to: (1) integrate existing collaborative STEM projects for the purpose of broadening participation in STEM programs, (2) encourage broader uses of collaborative strategies and the introduction of innovative programs among STEM faculty, and (3) identify institutional or departmental barriers to collaborative work.

The I^3 office would be headed by a STEM faculty member chosen from among those involved in NSF-supported collaborative projects. The office would be advised by the K-State Associate Dean's Council and an Internal Advisory Board (IAB). Led by Associate Vice President for Research Guikema, the K-State Associate Deans' Council is comprised of the Associate Deans for Research of the nine K-State Colleges and meets on a monthly basis to discuss issues related to research and scholarship. This group is aware of the various STEM research projects being conducted across the university and could identify and share opportunities for collaborative STEM projects with faculty members. The IAB would be made up of faculty members who have a record of commitment to broadening participation in STEM programs and integrating research and education. Some of these faculty members are PIs of EHR projects, others lead allied efforts, and still others are directors of NSF research projects.

Activity 2

In order to link integration with innovation it is important to capture the synergistic relationships of the collaborative STEM programs. In addition, it is essential to capture the elements that make a program successful and replicable under given circumstances. As previously stated, the culture of collaboration at K-State is valued; however, it is neither widespread nor well integrated with larger institutional goals. It is imperative that we, as an institution rather than as isolated programs, understand what works under what circumstances. Therefore, we plan to build an internal evaluation capacity that will support

local program assessment, the identification of best practices, and central administration prioritization.

The Office of Educational Innovation and Evaluation (OEIE) has been in operation for over ten years and has been instrumental in providing evaluation services for several of the named projects and collaboratives, such as ADVANCE, Biofuels, CORES, Ecological Genomics, EIDRoP, INSIGHT, GRoWE, K-State-Olathe, and most recently the IGERT:I-STAR. Lessons learned during each of these projects have been beneficial in isolation, but it is clear that collective lessons learned have the potential to be much more valuable to the institution.

Under a shared goal of broadening participation in STEM programs, we proposed developing an evaluation infrastructure to promote increased assessment capacity, identify best practices specific to K-State, and develop a prioritization framework that will assist faculty members and administrators in determining the effectiveness of program investments. The goals of this activity are to: 1) adopt national best practices in assessment; 2) create a library of evaluation elements and tools that can be utilized by the I^3 partner programs to easily and rapidly create instruments specific to K-State; 3) provide a global evaluation of university-wide programs' efforts designed to broaden participation in STEM programs; 4) utilize the global evaluation findings (meta-evaluation) to serve as baseline/benchmark for longitudinal studies; and 5) foster integration of research and education. This effort is in process using internal funding.

Activity 3

CORES was designed with the decentralized character of the institution in mind and introduced a shared infrastructure that enabled each participating program to maintain its own structure and activities. A common website[13] serves as a portal for 24 programs, providing students and families with a single, easily accessible entry point to all of the STEM outreach, recruitment and retention programs currently associated with CORES.

The CORES project also created a database of participants in its partner programs, which enabled individual program directors to: 1) identify and recruit students eligible for partner programs; 2) obtain data to support future grant proposals and to analyze data for use in research publications; and 3) allow tracking of students to determine the impact of these programs on K-State enrollment. Recently established partnerships with both the Office of Admissions/New Student Services and the Graduate School will enable these units to access the CORES database for recruiting new/transfer undergraduates and graduate students. In exchange, these two units are providing institutional support to maintain the database. Letters of support from the leaders of these programs document their commitment. The CORES database will provide the baseline data and tracking capability required for I^3.

The programs participating in CORES serve a variety of purposes and target populations but share a common

focus on broadening participation in STEM programs by increasing the number of individuals from underrepresented groups. (As shown in Figure 1, with example programs listed in the K-14 and the Undergraduate and graduate research/retention boxes.) About half of the programs serve pre-college students or community college students and thus have a focus on recruiting future STEM students through outreach events. GROW, described above, is one example. The GK-12 projects and the K-State Robert Noyce Scholarship project will build additional linkages with K-12 schools. The newly developed K-State Olathe campus (K-SO) offers opportunities for direct links with the Olathe School District as well as other school districts in Johnson County, KS. In addition to a series of outreach efforts, One Health Kansas is supporting collaboration with three community colleges for the delivery of a public heath course and building an educational pipeline for the masters in public health program. Other CORES programs, such as ELITE and K-State STEP, focus on the retention of STEM students at K-State.

Given that a shared infrastructure is in place and program directors have seen the value of collaboration, the CORES programs seemed an excellent cohort with which to explore increased integration. In conjunction with the CORES leadership, the I^3 Office would be responsible for directing these integration activities. These activities include: (a) developing a comprehensive picture of the programs, populations served, and measures of success; (b) examining current data in an effort to explore the extent to which participation in one program leads to participation in a second program as well eventual enrollment at K-State; (c) identifying outreach or retention gaps (e.g. groups not being well served by current programs); (d) developing a set of "best practices" gleaned from the internal evaluation effort (Activity 2) and discussions among project directors; and (e) working with faculty and graduate students to create innovative programs that are a direct result of the synergy established through these activities. *Rising Above the Gathering Storm*[14] makes the case for the need for diversity. The importance of strengthening K-12 science instruction in order to increase the number of students open to STEM recruitment and retention[15] as well as effective minority recruitment and retention practices[16] also are well established in the literature. In a sense, these activities focus on creating a learning community among projects involved with recruitment or retention efforts for the purpose of developing a shared knowledge of the relevant research literature as well as locally specific best practices.

The net result of the suite of actions proposed as part of Activity 3 would be to build an infrastructure that allows programs to better integrate their efforts and be more effective at broadening participation. With regard to the programs involved in K-14 linkages, the goal is to develop a series of STEM educational and career pathways. With regard to institutional retention programs, the goal is to build the institutional capacity to foster STEM diversity. We intended to create a

culture in which broader impact activities are institutionalized.

Activity 4

In *They're Not Dumb, They're Different: Stalking the Second Tier*, Tobias[17] explored why otherwise intellectually capable students avoid STEM fields. A recurring theme was the focus on problem solving skills to the exclusion of any larger intellectual overview or story line. Faculty members were the keepers of knowledge and students were expected to mimic the problem solving skills modeled for them in class. "Why" and "how" questions related to the various theories were never asked and the "second tier" students often wondered how various concepts were connected to one another. Tobias' second-tier students rarely learned about unanswered questions or cutting-edge research in their science classes. In presenting only what is known, introductory science courses lead many students to assume that there isn't anything left to discover.

REU and RET programs offer one strategy for engaging students and teachers in the process of discovery. In a recently completed EPSCoR project, Spears and Montelone explored strategies by which high school science teachers could integrate elements of K-State faculty research into their classrooms, strengthening students' understanding of the process of inquiry as well as demonstrating that there is more to be discovered in the sciences. Interdisciplinary research offers a particularly rich environment in which to explore linkages to outreach and recruitment/retention programs. Many of the "why" and "how" questions that Tobias' auditors hungered for are raised through the process of combining different disciplinary approaches and exploring new connections. No single faculty member is the expert; all are deeply engaged in the process of inquiry. The very process of examining a phenomenon or problem from multiple perspectives invites innovation.

We proposed extending the CORES linkages with K-14 outreach and undergraduate and graduate research/education to interdisciplinary research projects. In conjunction with the CORES leadership, the I^3 Office would be responsible for directing this activity. This included convening a working group of current participants in interdisciplinary research who will be responsible for: (a) developing illustrative case studies of how interdisciplinary research has been integrated into outreach, recruitment, and retention efforts; (b) designing and delivering faculty workshops on strategies for addressing "broader impacts" in research projects, both disciplinary specific and interdisciplinary; (c) providing seed funding and technical assistance to support innovative projects; and (d) identifying a set of strategies and "best practices" gleaned from the internal evaluation effort (Activity 2) and discussions among project directors. Included in the proposal budget were funds to support partial salaries for faculty members, postdoctoral fellows and graduate students in years two through five of the project to participate in the development of innovative programs based on their research.

Anticipated Outcomes of I³

An ultimate goal of I³ is to broaden participation in STEM programs. However, a secondary goal is building institutional capacity to support the integration of research and education. The first two activities would allow us to build an infrastructure consisting of a faculty-led convening authority and an internally maintained evaluation component designed to inform both the development of effective programs and the integration of those programs in support of university-wide goals. The third activity would allow us to test this infrastructure on a set of programs with a prior history of limited collaboration. The fourth activity would be the most challenging, in that only a couple of projects have tried to link interdisciplinary research with outreach, recruitment, and retention programs.

Example of a Current Collaborative Project: One Health Kansas

One Health Kansas[18] (Program Directors L. C. Freeman and B. A. Montelone) was funded by the Kansas Health Foundation to:

- Promote awareness of interconnections among human, animal and environmental health
- Build the pipeline of public health professionals
- Provide broader and more in-depth education to current and future professionals
- Develop a public health workforce capable of addressing emerging and re-emerging zoonotic diseases

The organizational chart for One Health Kansas, shown in **Figure 2**, builds on relationships with faculty researchers, a graduate program (MPH), the K-State Olathe campus, community colleges, K-12 school districts, CORES, Center for Science Education, and other universities. A series of collaborations is the key to managing this complex integrative project.

Example of Linkage of Research and Education: BRI

K-State's Biosecurity Research Institute (BRI)[19] is a $54M research and education facility with Biosafety Level 3 (BSL-3) and BSL-3Ag research capabilities. It features 14 research laboratories, small and large animal holding, plant growth chambers, an insectary, and a unique space dedicated to food safety research on an industrial food processing scale. The BRI includes an education and training wing with a classroom and mock training laboratory in which scientists, students, and staff can undergo training in general BSL-3 and BSL-3Ag practices as well as building-specific practices. Mobile camera systems in the containment and maintenance areas provide the opportunity for BRI to offer unique training opportunities for continuing education of scientists, veterinary practitioners, as well as mechanical and technical personnel.. A recently funded DHS Center of Excellence in Emerging and Zoonotic Animal Diseases will support collaborative and interdisciplinary research and education using the BRI.[20]

Summary

Although there are localized areas of collaborative work at K-State, the culture of collaboration is neither widespread nor well integrated with larger institutional goals. Under a shared vision of broadening participation in STEM disciplines and

integrating research and education, we proposed developing an institutional infrastructure to increase the synergy among existing programs, support assessment efforts that identify practices best suited to the economic and social climate within which K-State operates, broaden STEM faculty involvement in collaborative activity and innovative programming, and guide programmatic/policy decisions at departmental, college, and university-wide levels.

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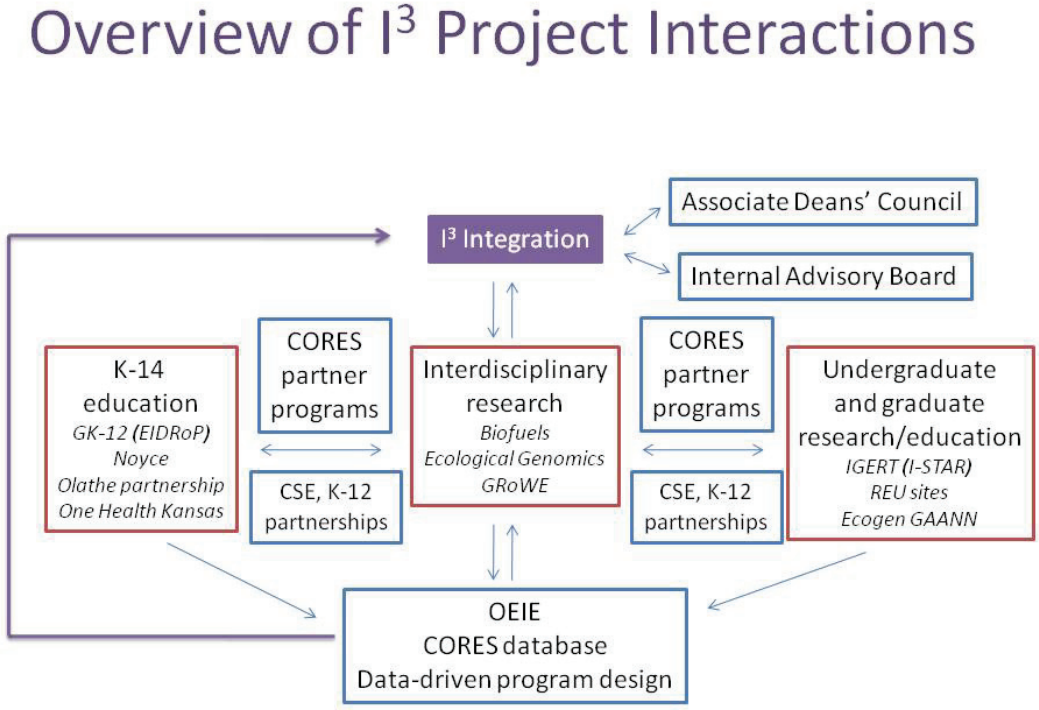

Figure 1. Example of interactions that will occur among personnel and organizations in proposed I3project.

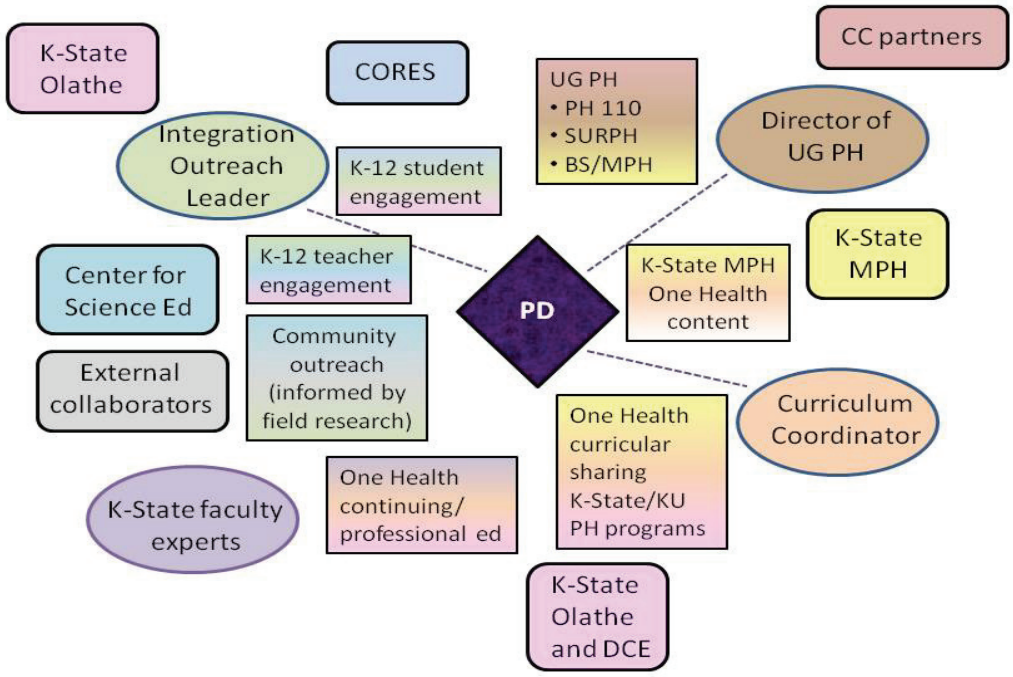

Figure 2. Interactions among One Health Kansas personnel and partners to accomplish project initiatives.