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CUR Focus

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Multiple Contexts, Multiple Outcomes, One Conceptual Framework for Research Skill Development in the Undergraduate Curriculum

Undergraduate curricula in many disciplines may be re-engineered to develop the research skills of the majority of students. This paper explores the development of research skills embedded in regular curricula and the assessment of the resulting outcomes in numerous contexts, in order to contribute data allowing comparative analysis of the value of undergraduate research.

This paper considers research experiences designed for all students enrolled in any regular undergraduate course and provides an overview of faculty members' use of a particular conceptual framework, in multiple contexts, to incrementally, coherently and explicitly develop student research skills. This equitable student exposure to research experiences may enable more students to develop interest in, and the skills associated with, research than is possible with models based on mentoring, and may encourage more to continue on to graduate research. The use of one conceptual framework across numerous disciplines and institutions enables a comparative analysis that, over time, may provide evidence of the efficacy of the framework itself.

The conceptual model that informs this development and analysis is the Research Skill Development (RSD) framework (Willison, O'Regan, 2006), which incorporates six facets of research skills into a continuum of student autonomy in the conduct of research (Willison, O'Regan, 2007). The contexts drawing on the RSD framework vary widely, in courses from the freshman to senior years; in institutions ranging from research university to technology university to rural university; and from introductory academic programs to more advanced courses in science, health science, engineering, business, social science, and the humanities. Many of the faculty members involved in courses in all these contexts make up the team for the Research Skill Development and Assessment in the Curriculum project, funded by the Australian Learning and Teaching Council (ALTC, 2007).

The Research Skill Development Framework

It is not always the students who are rated as "academically able" who are most able to engage in research. Sometimes students who are successful taking exams are not able to pose questions or create appropriate research directions, whereas academically weaker students may excel (White, 2007). So providing research opportunities for as many students as possible is important to allow some of those with lower academic rankings to shine in a research atmosphere. Developing research skills in a whole cohort may add to their general academic environment by inspiring curiosity in studies generally and promote progression to graduate research (Bauer, Bennet, 2003).

However, a major difficulty with providing a greater number of students with research experiences is that unless students are specifically guided in investigation processes, they will often continue to operate in subsequent investigations at the level at which they entered the university (Chaplin, 2003). This means that care needs to be taken to incrementally develop students' research skills over a period of time to enable undergraduate students to take part in research. The role of the Research Skill Development framework is to enable faculty members to conceptualize incremental approaches to involving students in inquiry. The RSD presents six facets of research, in which students:

- embark on inquiry and thus determine a need for knowledge/understanding;
- find/generate needed information/data using appropriate methodology;
- critically evaluate this information or data and the process used to find or generate it;
- organize information collected or generated;
- synthesize and analyze and apply new knowledge; and
- communicate knowledge and understanding and the processes used to generate the advances, with an awareness of ethical, social and cultural issues (Willison, O'Regan, 2006).

In the RSD framework, these elements are elaborated in a continuum of five levels of student autonomy. The first three levels all describe "closed inquiry" in which the faculty members determine the starting point such as aim, purpose, or question; the processes to follow, such as methods and procedures; and the end point, such as the answer, resolution, intended audience, and style of presentation. A student who is considered to be working at Level 1 requires a high degree of structure and guidance, whereas a student working at Level 3 does so independently within all the parameters that have been set. Levels 4 and 5 describe open inquiry, where the starting point, processes, and end points are determined by the students. At Level 4 this is scaffolded, so that, for example, students would still be limited in their scope and be given objectives to meet. At level 5 the open inquiry is determined by the student with reference to the discipline. For all of these levels, the degree of academic rigour required to fulfill them will vary according to academic level, disciplinary expectations, and so on (Willison, Schapper, Teo, 2009).

The RSD framework is used to assess the extent to which students improve their discipline-specific research skills as assessed by faculty members using assessment rubrics generated by the RSD framework; improve their discipline-specific research skills as measured through pre- and post-course student questionnaires; and change their regard for research processes and research outcomes, also as determined through pre- and post-course questionnaires given to students.

The framework is also currently being used to assess differences in plagiarism rates among cohorts of students involved and not involved in courses utilized explicit research skill development; the rates of progression of students into graduate research and completion of graduate-level research; and former students' evaluation of their research skills once employed.

Constructing, Validating Assessment Tools

The primary assessment tools utilized are diagnostic assessments provided early in a course, followed by summative assessments provided late in a course. Many disciplines' assessments are available for download on the RSD web site (see Willison, O'Regan, 2006). These are typically pre-existing assessment instruments that have subsequently been reframed by the RSD framework. This reframing is done in terms of the purpose of these instruments, that is, to explicitly and coherently develop and assess research skills; and in terms of the ways that faculty members assign grades using assessment rubrics shaped according to the six facets of the RSD and focused on discipline-specific research processes. This is an assessment-first orientation to curriculum redesign, which takes into account that assessments are often the point at which students begin to engage with the curriculum.

One type of validation of RSD-based grading rubrics is demonstrated by a freshman human biology course that has used RSD-based grading criteria for four years. There has been a trend in the correlation between marks given for a literature-research task conducted in the middle of the first semester and the grades students receive for a field-based research task completed at the end of the second semester. Before the RSD was used to inform the grading criteria, the correlation of the two marks was 0.2. With RSD, this correlation significantly increased, to 0.57, ($p < 0.05$) in 2007 (Willison, Peirce, Ricci, *under review*).

Human Biology Students in their Freshman year gather data from the field for their Level 4, open-ended research

The most likely explanation is that, as the skills associated with the literature research were explicitly and incrementally developed, some of the skills associated with field research were also developed even before students went out into the field (Willison, et al, *under review*). This is one piece of evidence toward the validation of the specific assessment rubrics. In most disciplines and year levels, students typically improve by an average of one level of autonomy during a semester. However, this average masks the differential improvement among students. Some students assessed as stronger at the beginning of the course do not develop skills as quickly as others, and the strongest students at the end of the course sometimes are those who started out as average or weaker.

The second set of assessment tools is pre-course questionnaires and post-course questionnaires. Both contain the same fifteen Likert-scale questions and two open-ended questions. The first nine Likert-scale questions ask students to assess their discipline-based research through such statements as, "My ability to ask rigorous research questions in Business Law is good." The remaining six questions ask about attitudes to research, such as, "Research has trustworthy outcomes." Students in RSD courses are consistently demonstrating statistically and educationally significant increases in specific research skills in the

Human Biology Students in their Freshman year involved in a Level 2, closed research task

content of the discipline they are studying. For example, business law students emphatically indicated significant increases in "ability to generate procedures to produce information" in the discipline during the semester. Questionnaires in themselves cannot be classed as reliable, as reliability is a function of specific questionnaire data (Cohen, 1988), but results from the pre- and post-course questionnaires in different contexts are showing consistently high reliability measures, as determined by a Chronbach's Alpha score of greater than 0.8 (Willison, et al, 2009). This is also an oblique justification of the RSD itself, as half of the questions are directly related to the RSD facets.

With the use of a conceptual model that informs faculty members' assessment of students, their construction of the questionnaire, and their efforts playing a substantial part in determining success in achieving the outcomes sought, there is always the danger of promoting a "self-fulfilling prophecy." To minimise this peril, another dataset is gathered that is substantially different in type and timeframe from the others mentioned above. This dataset is transcripts of interviews with students one year after completing a course that has embedded RSD-based assessments. From these interviews, more considered, longer-term aspects of the use of the RSD emerge. This triangulation of data gives substantial multiple perspectives on the benefits and detriments of explicit attempts to develop research skills. In addition, the 2005 cohort of students taking human biology is being tracked to determine long-term benefits, if any, of an explicit focus on development of research skills.

Evaluation can only determine the success of the implementation of a conceptual model. However, if the model is useful, this will show over time. Overall, the justification for the RSD framework would be substantial positive student outcomes and minimal negative outcomes in a variety, but not necessarily all, contexts. Other forms of evaluation, including students' rates of progression to and completion of graduate research, and employers' assessments of the research skills of former students they have hired are currently being implemented.

Outcomes and Scalability

Students' discipline-specific research skills are, on average, measurably increased in courses incorporating RSD-based grading rubrics. Students in the year-later interviews frequently state that the research skills they learned help them with subsequent university studies and with their employment. As noted, freshmen in human biology courses who do well in their first-semester literature research tend to do well with the second semester field research (but not necessarily the second-semester exam). Due to students' differential development, some students develop minimal research skills, but they can be identified as "at risk" of performing badly in the field research, based on their grade on the literature research, meaning support can be targeted at them. Moreover, many of these "weaker" students, when interviewed later, still appreciate that the attempt to explicitly develop their skills was, in hindsight, very useful for them in subsequent studies, employment, or both.

A minority of students have indicated that the process was not helpful for them and that other disciplines assisted them more. In an intensive Introductory Academic Program for international students who are new to an English-speaking university, students indicated in interviews that, while the RSD was informative at the time, its longer-term usefulness was low because the skills learned were not used in their subsequent courses. This highlights the need for students' research skills to be developed in discipline-specific, content-rich contexts, as opposed to general courses attempting to develop transferable research skills.

Another type of useful outcome has been the steady increase in faculty members' use of RSD-based approaches. Faculty members teaching freshman human biology began to use an early version of the RSD (Willison, O'Regan, 2005) in 2005, and in 2006 were joined by faculty members teaching masters coursework in electronic engineering. In 2007, faculty members in nursing, agricultural science, petroleum engineering, business and psychology began to utilise the RSD in four additional universities. In 2008 faculty also adopted the framework in their classes in English, dentistry, veterinary science, computing science, education, human resource management, and tourism. An external review of the Research Skill Development and Assessment in the Curriculum project stated that the RSD is a very useful conceptual framework if it is fully adapted to the context in which it is used; therefore it requires time to be correctly set up (Nightingale, 2008). Outside disciplinary boundaries, programs that prepare students to gain entry to university are also utilising the RSD. At present, eight universities are known to be using the RSD in at least one discipline or context.

A high degree of cross-pollination of RSD-based ideas has been found across disciplines, first suggested by the move from human-biology classrooms to electronic engineering. Disciplines that may otherwise be unrelated may have similarities in how courses are taught and so prove useful to informing faculty members about how to structure research-skill-building activities and assessments. For example, business law uses scenarios, an idea familiar to dentistry faculty members who utilise problem-based learning scenarios. The RSD-informed grading criteria used by business law inspired dentistry faculty members to incorporate RSD approaches; (Snelling and Karanicolas, 2008) they subsequently have inspired at least three other disciplines with their use of Wikis to develop and assess student research skills. The RSD Web site provides access to the assessment rubrics of many disciplines' assessments, so that these may be downloaded, adapted, and used in new contexts. Multiple users in multiple contexts over time, each engaging in formal evaluation procedures, will provide substantial understanding about the benefits and limitations of the RSD framework and the approaches that it has inspired.

Programmatic Changes Based on Assessment

The most common change that faculty members indicate that they have made through the use of RSD-informed assessment tasks is they way they talk to their students. For example, class readings are more clearly framed as engagement with others' research agendas, which may both inform students about discipline-appropriate processes and provoke discussion about the veracity of each instance of research. Many disciplines are just completing their first semester of experimenting with RSD-inspired approaches and are still analysing pre- and post-course questionnaire results, as well as diagnostic and summative assessment results.

Further, faculty members in the disciplines that are into their second or subsequent years of RSD have responded to analyses of assessments, questionnaire results, and follow-up student interviews. Changes they have undertaken have included formally including RSD-based ideas in course literature, descriptions of course purposes, and in online environments; making development of research skills even more explicit to students in subsequent years; factoring in ways to help students make the most of RSD-rubric feedback; expanding the number of assessments utilising RSD-based rubrics in a course; expanding RSD approaches to other courses under the control of these faculty members; and involving additional faculty members in RSD processes.

Five different major approaches to implementing the RSD have been used so far, all of which have emerged in specific contexts and influenced other contexts. The first and most common is the use of RSD-informed assessment rubrics, pitched at an appropriate level of autonomy, to determine a student profile of performance for each assessment, and to track changes over the duration of the course. The second approach is more "lock-step," in which students are expected to demonstrate Level 1 autonomy with the required degree of rigour, before proceeding to Level 2, and so on. The third approach is to assess the six facets of RSD via student utilization of Wikis as a team research process and then to present their final research product as a poster or presentation. The fourth use of the RSD is to evaluate existing assessment tasks, to determine their strengths and weaknesses. Commonly the requirement for students to evaluate information or data is missing or underdeveloped. The fifth emerging use of the RSD is by faculty members considering how the framework may be used in the supervision of graduate research students. This last approach raises the importance of the segue between undergraduate and graduate study, as students who move on to further study may be more ready to conduct research due the explicit focus on developing research skills they have encountered in their earlier studies.

Conclusion

Explicit and coherent development of research skills in the curriculum is one way of enabling undergraduate students to participate in the benefits of undergraduate research. Only a few of these students may be developing knowledge new to humankind, but potentially all will be developing the skills associated with discipline-specific research. RSD-based approaches can overcome some of the difficulties associated with mentored research models, such as cost, the necessity of criteria to determine who may (and may not) participate, and the capacity to evaluate the success of programs.

An external reviewer of the RSD project stated, however, that the framework is not a silver bullet for courses; each context requires thoughtful adaptation of the framework to fit the university, discipline, course, and faculty personalities concerned, and this requires time and effort. Not all undergraduate students are prepared or willing to engage in more open-ended inquiry and may resist, resent, or find fault in RSD-based curricula. While early findings have been in general positive, these results should be approached tentatively, and trials and evaluation in each context must precede any policy about RSD implementation.

The Research Skill Development framework, used as a conceptual model to inform the explicit and incremental development of student research skills in the curriculum, has proven to be highly flexible, allowing faculty members to adapt it to their disciplinary contexts and enabling communication among disciplines and universities to inform and inspire a multiplicity of approaches. It has enabled the modification of standard assessments so that these fit into the one major agenda of developing students' research skills. Substantial gains have been recorded for most students involved in courses with RSD-based approaches. The RSD has enabled gathering of common data, allowed faculty members to measure changes in students' research skills over time, and allowed students to assess their own programs—all providing information that should help provide a basis for comparative analysis of the value of undergraduate research.

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CUR Focus

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URSSA: Evaluating Student Gains from Undergraduate Research in the Sciences

For eight years, our research group has been investigating the outcomes of undergraduate research (UR) experiences in the sciences for students, their advisors, their departments and their institutions. Based on our and other recent research on UR, we have developed a web-based survey we call Undergraduate Research Student Self-Assessment (URSSA). The goal of URSSA is to enable departments and programs to gather information about what students do or do not gain from participating in UR in the sciences, and about what activities contribute to those gains.

Background to URSSA

Our group, Ethnography & Evaluation Research, conducted a large qualitative study addressing fundamental questions about the benefits (and costs) of undergraduate engagement in faculty-mentored, authentic research undertaken outside of class work, about which the existing literature offered few findings and many untested hypotheses (for a review of this literature see Seymour, Hunter, Laursen, DeAntoni, 2004). Longitudinal and comparative, this study explored:

- what students identify as the benefits of UR—both following the experience, and in the longer term (particularly career outcomes);
- what gains faculty advisors observe in their student researchers and how their view of gains converges with or diverges from those of their students;
- the benefits and costs to faculty of their engagement in UR;
- what, if anything, is lost by students who do not participate in UR; and
- the processes by which gains to students are generated.

We chose as our study sites four liberal arts colleges with a strong history of UR because findings would represent the "best case." All four offer UR in three core sciences—physics, chemistry, and biology—with additional programs in (at different campuses) computer science, engineering, biochemistry, mathematics, and psychology. Undergraduate research in these institutions followed an apprenticeship model, where faculty worked closely with students throughout the summer—training, guiding, and mentoring them—on authentic research projects for which outcomes and answers were unknown.

We conducted multiple rounds of interviews with a cohort of students engaged in UR and with a comparison cohort who did not do UR. The faculty advisors working with the student cohort were interviewed, as well as a number of administrators with long experience of UR programs at their schools. A comparison group of faculty who were taking "time out," or who no longer conducted UR, was also interviewed. The total of 367 interviews produced more than 13,000 pages of text data. Following a qualitative research method, we conducted a content analysis on all the interview data. From this analysis we were able to identify the range, type and relative weighting of gains from UR experience that students reported (for complete details on our research method and design see Seymour, *et al*, 2004; Hunter, Laursen, & Seymour, 2007; 2008).

We found that the benefits students described fit six conceptual categories: personal/professional gains, gains in thinking and working like a scientist, gains in skills, demonstrating norms of professional practice and understanding how scientists practice their profession (the "becoming a scientist" category), gains in career clarification, and enhanced career preparation (Hunter, *et al*, 2007; 2008). In further analyses, we found strong congruence across the student, faculty and alumni data sets, showing the robust nature of the categories.

In updating our literature review for our forthcoming book, we did a careful analysis of the gains reported in other recent research and evaluation studies of UR. In comparing findings, we also found strong convergence as to the types of benefits: all gains reported by other studies sorted into the six benefits categories identified in our research. Findings from this study and others thus provide broadly documented empirical evidence of the types of gains that derive from learning research hands-on and the role of UR experiences in encouraging student researchers' intellectual, personal, and professional growth. Having comprehensively identified the range and type of gains to students from UR experience across multiple studies, we have designed URSSA to assess the many benefits reported.

Development and Validation of URSSA

URSSA has been methodically developed and is grounded in the research on the benefits to students of undergraduate research experience. We began by examining the empirical results to develop the survey categories and items. We piloted the draft survey in a round of "think aloud" interviews with four focus groups (each with four or five UR students) to capture the range and content of benefits reported, discuss and refine the wording of questions, and organize items in a coherent structure. Importantly, we designed URSSA's survey items and open-ended questions to focus on students' learning gains as program outcomes. That is, modeled upon the Student Assessment of their Learning Gains (SALG) instrument, URSSA gathers program evaluation data from students to assess what they *learn* rather than whether they liked their experience (see http://www.salgsite.org).

We shared these early versions of the surveys with other researchers studying UR and with directors of UR programs at research universities, master's-granting universities, and primarily undergraduate institutions to gather their feedback and to determine if we missed any items needed for program evaluation. Following revisions based on professional collegial input, we tested URSSA in a second round of "think aloud" interviews with another four focus groups (each with four or five UR students) to ensure that the intended meaning of the survey items was easily understood. Students were asked to fill out the survey (on paper, at this stage). Then, going through the survey, section by section, we asked students if any of the survey items were unclear, confusing or seemed redundant. We queried students as to whether the survey had missed any benefit that they had gained and asked them to comment on the length, completeness and coherence of the survey. Again, we revised the survey based on this feedback.

Most items are multiple choice or numerical ratings, with a few open-ended response items. For the gains items, ratings are on a four-point scale, from 1 = no gain to 4 = a great gain (and NA = not applicable). Likert-type items were developed to reflect degree of satisfaction with various aspects of the UR experience. Respondents rate these on a 4-point scale, from 1 = very dissatisfied to 4 = very satisfied. Finally, the helpfulness of program activities to students' learning is rated on a 4-point scale, from 1 = not at all to 4 = a great deal. A few open-ended questions address the quality of the experience, probe for particular types of gains, and seek advice for the program. URSSA takes approximately 10-15 minutes to complete.

This past summer, we conducted a nationwide pilot test to check reliability and validity of survey items across a range of formal and informal research programs in a variety of campus settings. We analyzed data for over 500 students who participated in UR at 22 institutions, including research universities, master's-granting universities, and primarily undergraduate institutions. Undergraduate research programs at these institutions varied in size. Because the survey was sent to students from their home UR program, we could not determine a response rate, but the numbers of students responding per institution varied from 3 to 93, with most between 19 and 51. We shared each institution's student survey results with the respective program directors for their own evaluation purposes.

Through Confirmatory Factor Analysis we compared how student responses fit the hypothesized structure of the survey and found that the data met accepted standards for model fit. We also tested survey items to learn if they functioned as anticipated; some survey items were removed from the survey or changed after not meeting criteria for acceptable item functioning. After revision, we will conduct final "think aloud" interviews with student focus groups and make any additional necessary changes. Our goal is to have URSSA up and running on the SALG website by summer 2009.

Measuring Student Gains with URSSA

The online instrument can be used for both summative and formative evaluation. For summative evaluation, URSSA provides a means to gather evidence over time about the success of the program to be shared with institutions, funders, and other stakeholders, while formative feedback is used to adjust the program for the future. For UR programs that currently use other surveys, URSSA can provide a source of comparative data.

A set of core items is fixed and cannot be changed. These measure student gains from UR across the six benefits categories and probe the general processes by which these are achieved. For summative evaluation, measurement of core benefits items provides evidence against an external standard: the gains documented in the literature. Thus URSSA is designed to measure students':

- personal/professional gains, such as gains in confidence and establishing collegial relationships with faculty and peers;
- intellectual gains, including the application of their knowledge and critical thinking skills to research work, as well as in extending their knowledge and understanding of connections among the sciences;
- gains in professional socialization, such as changes in students' attitudes and behaviors that indicate adoption of professional norms;
- gains in various skills (communication skills, technical skills, computer skills, etc.);
- enhanced preparation for graduate school and the workplace; and
- gains in career clarification, confirmation and refinement.

Survey items include some designed to assess different levels of intellectual gain, such as gains in learning about the process of science and understanding how research is done (reported most commonly by students). Items also query higher-order intellectual gains, namely, in understanding how to pose and investigate a research question and in understanding how scientific knowledge is constructed (both reported less commonly by students). Although active participation in UR offers the potential for students to move through a sequence of intellectual gains—from application to design to abstraction—research findings indicate that this process is neither easy nor guaranteed, and very likely requires students' sustained, long-term involvement.

Our research has highlighted the role of UR in socializing students to the profession of science research, which, to date, has not been extensively documented in the literature. URSSA survey items probe changes in students' attitudes and behaviors that reflect characteristics seen as requisite to the profession and query whether and how UR affects their understanding of science as a profession and of the norms that guide professional practice. These types of gains indicate students' growth as young professionals and point to the more subtle, affective benefits of UR experience.

Other survey items aim to determine the impacts of UR experience on students' choice of career pathway: how it influenced decisions for or against graduate school, informed their view of research as a profession, or enabled them to test their interests and temperament against the realities of day-to-day research work and to assess whether a career in science research "is right for me."

We have used URSSA in evaluations for UR programs run by the Biological Sciences Initiative (BSI) and the National Institutes of Health (NIH) Scholars program at the University of Colorado, Boulder, and for the Louisiana Science, Technology, Engineering and Mathematics (LA-STEM) Research Scholars program at Louisiana State University. Use of the URSSA survey is proving useful in detecting differences and issues of importance. For example, Thiry's (2008) report for BSI and the NIH Scholars program shows that older and more experienced students report higher gains in professional socialization, while novice researchers report greater gains in "thinking and working like a scientist." For the LA-STEM program, which aims to improve student retention and encourage science career pathways, URSSA showed the efficacy of particular program elements, such as program staff support and a strong peer community, in achieving program objectives (Thiry, Hunter, 2008).

Advantages of URSSA

URSSA will have a good deal of flexibility to address different institutional contexts and a variety of program types and thus will be useful for gathering formative feedback about the program. By selecting from a menu of optional items, program directors or departmental UR administrators will be able to tailor the survey to assess the contributions of specific program elements (i.e., career seminars, field trips, writing workshops, etc.). In addition to collecting demographic data, URSSA will allow departments and program directors to track other issues of importance, such as how students found out about UR at their institution, their reasons for undertaking UR, or whether the availability of UR opportunities was an important factor in students' choice to attend the institution. We are unaware of any other UR instrument that allows users this degree of flexibility.

Once URSSA is fully implemented, it will be available at no cost to UR program directors and departmental UR administrators. URSSA users will be able to view numeric results as raw data, summary statistics, cross-tabs, and graphs. They will also be able to download a report with all questions and data in a preformatted Excel report. We are also working to add a qualitative data analysis function to the site. This function will enable users to qualitatively and quantitatively analyze the content of students' comments in response to open-ended questions, allowing UR administrators to take full advantage of the data. This capacity may be of particular value to URSSA users because, as we have found, UR students are quite able to give insightful feedback on their summer research experiences.

Limitations of URSSA

Lopatto (2007) argues that student learning and experience may be most directly assessed through self-report. Certainly our qualitative study of UR indicates that students have substantial self-awareness of their own growth and of the processes through which it accrues. Thus, student self-report is one important tool in the evaluation toolkit for any UR effort. In our experience with URSSA, we find that students can reliably assess their own gains in areas already familiar to them—for example, gains in content knowledge or laboratory skills—and personal growth. However, student self-assessment in new domains, such as understanding the nature of science, is less useful in distinguishing degrees of gain. As novice researchers, students are simply not aware of how much more there may be to learn. We continue to refine our survey to include items that capture these gains appropriately. In future work, we hope to develop tools complementary to URSSA that are useful for gathering assessment data from advisors and other informed sources.

The question also arises as to whether URSSA is applicable in measuring outcomes of UR in fields outside the sciences. Because URSSA is grounded in the research on UR in the sciences, it is neither written for nor validated for use in non-STEM fields, where the traditions, practices and outcomes of UR are less well established or characterized.

To protect the anonymity of student answers, URSSA is used only for student groups of 10 or more who participate in science research through their departments or in organized programs. It is not suitable for individual laboratories or for the assessment of research mentors. However, the questions offer topics that individual advisors can discuss with their students to gather feedback for their own use.

For more information, and to review a working, preliminary version of URSSA online, see:

http://www.surveymonkey.com/s.aspx?sm=vBY1ie_2f4fE_2bdZIX11IlhFQ_3d_3d

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CUR Focus

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A Longitudinal Student Outcomes Evaluation of the Buffalo State College Summer Undergraduate Research Program

The Program

Buffalo State College (Buffalo State) is the largest of the 13 colleges of arts and sciences in the SUNY (State University of New York) system. Its total enrollment is nearly 11,000, with an undergraduate enrollment of 9,139. Experiential pedagogies, including undergraduate research, are reflected across the undergraduate programs and Buffalo State College has placed increasing emphasis and resources on expanding undergraduate research opportunities for students in all academic disciplines. Our use of the term 'research' is broadly defined by the standard practices established within each academic discipline and includes scholarship and creative activities. It is assumed that the activity will produce original results and contribute to the body of knowledge and creative works within a discipline.

Coordinated campus-wide undergraduate research opportunities were introduced at Buffalo State more than ten years ago. In 2003, as part of the College's efforts to institutionalize undergraduate research, an Office of Undergraduate Research was established and a half-time director was appointed in order to better promote and expand opportunities for students to participate in undergraduate research. This office administers programs to support academic year and summer research, including travel support for students to present at conferences and juried art shows; supply and travel support for small projects; faculty development to support efforts to integrate research into a new or revised course; and an annual campus-wide celebration of research and creativity activities. The summer research program supports eight weeks of full-time research, scholarly, and creative activities. Each award provides a student stipend of $2,500, a faculty stipend of $1,000, and $500 for travel and supplies to support the project. Since the inception of the summer research program, a total of 112 awards have been made. Program guidelines and a link to the online application for the summer research program can be found at http://www.buffalostate.edu/undergraduateresearch/x504.xml. All of the programs administered by the Office of Undergraduate Research are supported by Buffalo State funds, including a portion of overhead derived from external grants. Table 1 provides an overview of the Buffalo State undergraduate research programs.

Amelia Alessi, summer research student, assessed population diversity in Bald Eagle populations in the Northeastern United States. She traveled to Maine in order to help collect feathers from young eagles.

Buffalo State undertakes regular evaluation of all academic programs, including those programs administered by the Office of Undergraduate Research. The design of the evaluation effort is determined by the program and evaluation results are included as part of the program's annual report. Because the summer research program was one of the longest running programs (now entering its eleventh year) and accounts for nearly half of the annual operational budget of the Office of Undergraduate Research, it became the focus of our most recent evaluation efforts.

Background of the Evaluation

We were interested in developing a program evaluation that could provide a reliable assessment of the impact of our summer research program on the student participants. There have been many valuable studies of the effects of undergraduate research on participating students. These studies have identified many possible impacts of undergraduate research and have raised a number of important issues associated with this teaching pedagogy. Most of this work has relied on interviews

Table 1: Buffalo State Undergraduate Research Programs

Program	Description	Size of Award
Small Grants	Program assists students in carrying out research and creative activities during the academic year. The award is designed to help defray the cost of travel, supplies, and other materials necessary to conduct the project.	$400
Undergraduate Travel	Program provides partial support for students to attend conferences. Eligibility requirements require that the student be the first author on the abstract or artist statement. As funds are available, faculty mentors may also receive travel support to accompany the student.	$400 Higher amounts for international travel
Integration of Undergraduate Research into the Curriculum	Program supports the development of new courses and/or the revision of existing courses to include a substantial undergraduate research component. Course can be at introductory or advanced level and designed for non-majors or majors.	$750-1000
Summer Research	Program supports eight weeks of full-time research, scholarly and creative activities.	$4000
Student Research and Creativity Celebration	Annual event provides students an opportunity to present their preliminary and completed research and creative activities. A variety of presentation formats are possible: theatrical and musical performances, gallery exhibits, posters, talks, and demonstrations. Individual, small group and class projects are eligible.	Not applicable

with or surveys of student participants and/or faculty advisors who were asked to identify the benefits of the undergraduate research experience (see e.g., Merkel, 2001; Seymour, et al, 2004; Lopatto, 2004; Hunter, et al, 2007). Singer sought an evaluation that, while it might include survey and interview methods, also would go beyond such measures to develop a wider array of evidence bearing on program impact. Many undergraduate research programs, moreover, have focused largely on students in science, technology, engineering and mathematics (STEM) disciplines, whereas the Buffalo State program makes a point of also recruiting students from the arts and humanities, and Singer felt it important to develop measures that would capture the program's impact on these students as well as outcomes for STEM students.

Singer therefore contacted a consulting firm that specializes in the independent evaluation of educational programs (Weiler) whose work she was familiar with from other projects in which they had both been engaged, to discuss ideas for how such an evaluation might be designed and implemented. This article describes the objectives, design approach, protocols and procedures of the evaluation that emerged from that initiative.

Evaluation Objectives

We agreed that an evaluation of the summer research program should have four purposes. The evaluation should: (1) obtain reliable assessments of the program's impact on participating students, based on a variety of measures; (2) provide information to participating students that clarifies what we hope they will learn and provides a mechanism to help them assess their academic strengths and weaknesses; (3) begin the creation of a longitudinal database that can provide data on the impact of undergraduate research on a range of outcomes for students from a variety of academic disciplines; and (4) serve as a model that could be adapted by other institutions to evaluate their own UR programs.

Design Approach

We decided to begin by creating a list of broad outcomes that faculty from a variety of disciplines wished to measure, together with language that would spell out in more concrete detail the specific elements of each outcome that should be measured. This initial product would serve as the basis for the drafting of an assessment instrument to be used by faculty mentors of students in the program. Accordingly, Singer organized and we both led a two-day meeting at Buffalo State in June 2006 of a faculty working group consisting of nine faculty members from eight different disciplines. The working group identified a wide range of student outcome categories of interest and drafted language that defined the specific outcome components of interest for each category. With this initial guidance from Buffalo State faculty, Weiler drafted a comprehensive evaluation design and we collaborated to refine and flesh out the draft outcome categories and components identified by the working group.

Evaluation Pilot Study

Our preliminary evaluation design included:

- a student survey designed to provide faculty mentors with information about participating students as they embarked on their summer research projects;
- preliminary student assessments made by faculty (using the outcome components described above), based on information from the student survey and initial student interviews;
- preliminary student self-assessments, using the same instrument employed by faculty;
- journals to be kept by both students and mentors, for faculty to record observations pertinent to their assessments, and for students to keep track of their progress and as a resource for discussions with their faculty members
- mentor and student mid-point and final progress reports, including assessments and self-assessments, respectively;
- mentor and student group discussions, to probe in depth their perceptions of summer program strengths and weaknesses, benefits, recommendations for changes, etc.; and
- an alumni survey, to obtain retrospective student views on program strengths and weaknesses and perceived benefits.

We arranged to pilot test these evaluation components and instruments (except for the alumni survey) during the 2007 summer research program, using five pairs of students and faculty mentors from four different disciplines. The pilot included both experienced and new mentors, to ascertain whether academic discipline or degree of mentor experience made any difference to student and mentor views on the relevance and usefulness of each evaluation component and the ease of use of evaluation instruments. Following the pilot test, we held separate group discussions with the participating faculty and students. The discussions confirmed that both faculty and students found the evaluation instruments easy to use, while at the same time there was some concern that the multiplicity of required evaluation components was more burdensome than necessary and that some simplification of the instruments would be useful.

Revised Evaluation Components

With the input from the fall 2007 group discussions and important contributions from Carol Beckley, a faculty member in the Theater Department, we refined the evaluation for use across the entire 2008 summer research program. In our pilot effort, we had asked mentors and students to make broad outcome assessments on a four-point scale after reviewing language that specified the components of each outcome. For example, we asked for an assessment of student "creativity," and provided language that described four distinct characteristics of that outcome, (discussed below). Feedback from the faculty mentors pointed out the problems from assigning a single score to represent several components within a single outcome category. This often caused the mentor to either ignore a component or average the range; in either case, information was being lost. A second request from the focus group participants was for a greater range for the outcome scores (changing from a four-point to a five-point scale) and the addition of a 'not applicable' option. These changes were incorporated into the revised instruments used in the full-scale study conducted in the summer of 2008.

The evaluation, which we intend to use again during the summer programs of 2009 and beyond, has the following components. All of the instruments and guidelines described below can be found (as static versions) on a link from the Buffalo State Office of Undergraduate Research website http://www.buffalostate.edu/undergraduateresearch/x561.xml

1. Student survey. Students who are accepted to the program complete a survey designed to provide information about their motivation, knowledge and expectations, and their understanding of their academic strengths and weaknesses. The survey has two main purposes: (1) to provide faculty mentors with insights

Table 2: Student Outcome Categories Assessed as Part of the Evaluation

Communication
Creativity
Autonomy
Ability to deal with obstacles
Practice and process of inquiry
Nature of disciplinary knowledge
Critical thinking and problem solving
Understanding ethical conduct
Intellectual development
Culture of scholarship
Content knowledge skills/methodology

into student knowledge and thought processes, as an aid to the mentors in completing preliminary student assessments; and (2) to provide students with a structured opportunity to explore their own goals, knowledge, and readiness for the program. (The mentor's copy of the survey instrument shows the relationship between each survey question and relevant student outcomes.)

2. Student intake interview. Faculty mentors conduct "intake interviews" (intended more as conversations than formal interviews) with the students they will be working with, in order to help the mentors learn enough about the students to formulate preliminary assessments. Mentors are encouraged to probe the students about their answers to the student survey and to ask additional questions if necessary. The mentors are provided by the evaluation with a list of candidate questions for this purpose, showing the relationship between each candidate question and relevant student outcomes.

3. Mentor's preliminary student assessment. Faculty mentors are provided with an assessment instrument that lists 11 outcome categories, including the specific components of interest for each category. For each outcome component, the mentors are asked to give their students a preliminary score on a five-point scale (the student *always, usually, often, seldom* or *never* displays the outcome of interest, unless the component is *not applicable*). In addition, given that mentors may not have equally rich or compelling information about their students across every outcome component listed, the mentors are asked to indicate, for each score, their level of confidence in the score (*very, fairly, somewhat, not terribly*, or *not at all* confident). Table 2 shows the student outcome categories employed for these assessments.

On the assessment instrument provided to the faculty mentors, each of these outcome categories includes a list of the specific outcome components that faculty are asked to assess using the five-point scale described above. For example, for the outcome category called "creativity," the components to be assessed are:

- brings new insight to the problem at hand;
- shows ability to approach problems from different perspectives;
- combines information in new ways and/or demonstrates intellectual resourcefulness; and
- effectively connects multiple ideas/approaches.

For the outcome category called "ability to deal with obstacles," the components to be assessed are:

- learns from and is not discouraged by set-backs and unforeseen events; and
- shows flexibility and a willingness to take risks and try again.

This pattern is followed on the assessment instrument for all 11 outcome categories. The instrument provides space for the faculty member to indicate his or her assessment score and confidence level, as well as space for indicating why an assessment score has changed between preliminary and later assessments (discussed below).

4. Mentor journals. Mentors are strongly encouraged, but not required, to maintain written records in the form of informal journals in which they record observations, analyses, comments, questions and conclusions that are relevant to the student outcomes they are being asked to assess.

5. Student preliminary self-assessment. Students in the program complete the same assessment instrument described above in Step 3.

6. Mentor-student meeting to compare assessments. Mentors and students meet in order to compare assessments and discuss the reasons for any differences. These discussions are intended to provide the mentors with information about the extent of their students' self-knowledge, provide the students with opportunities to obtain more realistic assessments of their strengths and weaknesses, and make program expectations explicit and transparent so that students can strive to excel on each outcome where they are being assessed. The discussions also give the students opportunities to bring new information to bear on their mentor's preliminary assessments.

7. Student journals. Students are strongly urged, but not required, to maintain a journal in which they can record their questions, concerns, ideas and observations at they conduct their summer research projects. They are provided by the evaluation with journal guidelines that include a list of candidate topic areas (ideas, hypotheses, observations, evidence, obstacles, etc.) to bear in mind as they proceed.

8. Mentor and student mid-project assessments. Approximately mid-way through the summer research projects, mentors and students repeat Steps 3 and 5 as part of their mid-project progress reports. The mentors and students both indicate, where appropriate, the main reasons for any change in their assessment/self-assessment scores since their preliminary assessments conducted at the outset of the program.

9. Mentor and student final assessments. At the completion of the summer research program, mentors and students repeat Steps 3 and 5 as part of their final reports. The mentors and students both indicate, where appropriate, the main reasons for any change in their assessment/self-assessment scores since the mid-project assessments that they conducted approximately half-way through the program.

10. Alumni survey. Students who have completed the summer research program in 2008 will be asked a year later (i.e., in the fall of 2009), to complete a brief survey soliciting assessments of their undergraduate research experience along various dimensions. An alumni survey will likewise be sent to the 2009 participants in the fall of 2010, and so on.

The instruments described above – mentor and student outcomes assessments, student survey, alumni survey – are all designed to be completed on a website accessed by authorized users, with the resulting data flowing automatically to a database maintained by a Buffalo State-based evaluator responsible for the data analysis. The web-based format permits "unlimited" comments to be entered by mentors and students in providing explanations for differences in assessment scores between the preliminary, mid-project and final assessments. Mentors and students who maintain journals are also encouraged to do so in computer format. The evaluation instruments discussed above cover a wide range of potential student outcomes and should be readily adaptable to a variety of undergraduate research programs, both summer and academic year. Other institutions may wish to adapt these evaluation instruments to reflect the emphases of their own undergraduate research programs and the particular interests of their own faculty.

An analysis of the first round of data from the evaluation (from the 2008 summer research program at Buffalo State) is currently being conducted and will be reported in a future article and on the Buffalo State Office of Undergraduate Research web site. The analysis report will include a comparison group study that was not part of the evaluation design but is being conducted independently by another member of the Buffalo State faculty.

Concluding Remarks

Our efforts to determine the impact of the summer research program are ongoing. Initial feedback from the faculty and students who participated in the summer 2008 program included a suggestion to reduce the number of assessment surveys (perhaps by replacing the mid-summer survey with a shorter version). Both mentors and students found the initial interview helpful, particularly when the student and mentor had limited prior interactions. They also reported that mentor-student conversations after completion of the assessment surveys facilitated the sharing of ideas and a review of student progress. The students especially liked learning more about how they were doing.

The evaluation also may provide an opportunity to shed some light on a long-standing methodological debate. In all student self-reports, whether they are part of local or national surveys or end-of-course evaluations at a school, the chronic criticism is that students cannot be trusted to make good self-assessments. Our evaluation at Buffalo State could provide an opportunity to test the validity of student self-assessments by studying the concordance or discordance between student and mentor assessments. If student self-reports become more credible with each round of evaluation, we might hypothesize that our evaluation has cultivated "metacognition" in students.[1]

1 The authors are indebted for this point to David Lopatto, Samuel R. and Marie-Louise Rosenthal Professor of Natural Science and Mathematics, Psychology Department, Grinnell College

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CUR Focus

Using Electronic Portfolios to Measure Student Gains from Mentored Research

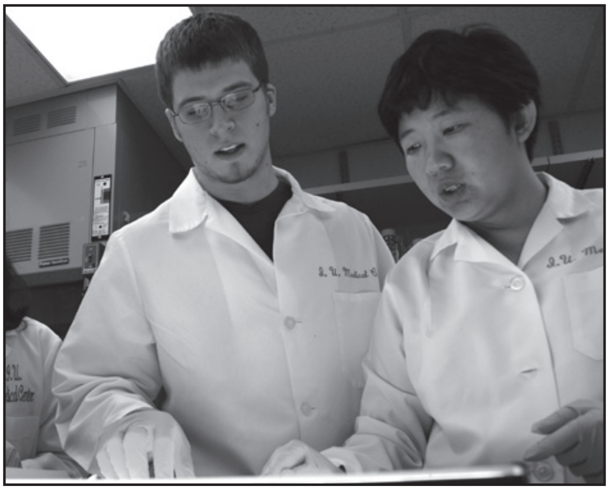
The Assessment Rational and the NSF Electronic Portfolio (ePortfolio)

The cumulative personal and professional benefits of completing an undergraduate research experience project are varied, interwoven, complex and, in some cases, not easily measured. Nonetheless, prior work has shown that students who are involved in undergraduate research: (1) gain self-confidence (Ferrari, Jason, 1996; Campbell, Skoog 2004; Houlden, et al, 2004), (2) are more likely to complete their undergraduate education (Nagda, et al, 1998; Ishiyama, 2001), and (3) are more likely to go onto graduate school compared to students who do not have a research experience (Kremer, Bringle, 1990; Chandra, et al, 1998; Alexander, et al, 2000; Foertsch, Alexander, Penberthy, 2000; Ishiyama, 2001; Bauer, Bennett 2003). Descriptive studies suggest students gain intellectually as a result of an undergraduate research experience (Hakim 1998; Kardash, 2000; Hathaway, et al, 2002). A few well-designed assessment studies show that students involved in undergraduate research *self report* intellectual gain from such experiences (Ishiyama, 2002; Seymour, et al, 2004; Lopatto, 2004; Russell, et al, 2007). Nevertheless, there are few objective assessment tools for measuring the effects of undergraduate research experiences on student learning, and attempts to conduct objective assessments have rarely been attempted.

Descriptive studies suggest student-faculty interactions during an undergraduate research experience play a key role in enhancing student confidence (Blackburn, et al, 1981; Jacobi, 1991; Koch, Johnson, 2000), student retention, and academic growth (Pascarella, Terenzini, 1991; Astin, 1993; Tinto, 1998). In 2005 and 2006, the Faculty Survey of Student Engagement (FSSE) and the National Survey of Student Engagement (NSSE) sampled over 29,000 faculty and more than 65,500 seniors at 209 four-year colleges and universities. These surveys could not match student/mentor collaborators, but taken together, indicated a positive relationship between student engagement in "educationally purposeful activities", such as research participation, and outcomes including critical thinking, grades, and "deep learning" (Kuh, et al, 2007) Deep learning is defined as "learning that encourages students to process information in ways that help them make qualitative distinctions about the merits of data-based claims or the persuasiveness of logic-based arguments" (Kuh *et al*, 2007, pg. 40). Contemplating the "value added" by undergraduate research, one hopes that in addition to gaining self-confidence and increasing persistence and graduation rates, it also promotes student intellectual growth.

In addition to the dearth of objective studies documenting student intellectual gains, studies that objectively examine the role mentoring plays in the undergraduate research experience are lacking. We suspect the quantity and quality of mentoring students receive during research projects varies considerably depending on the students' academic disciplines, the environment they work in, and characteristics of individual mentors. Studies have shown that students mentored by a faculty member were more satisfied with their research experience than those mentored by someone other than a faculty member (Shellito, et al, 2001). The recent NSSE and FSSE studies, surprisingly, show that the amount of time the faculty member spends doing research does not seem to affect the probability students will participate in research, collectively, at an institution. Rather, the higher the value faculty members at an institution place on this activity the more likely students will report greater progress in key learning outcomes (Kuh, *et al*, 2007). Such studies do not fully answer questions about skills students gain, nor do surveys of student satisfaction with faculty mentoring speak fully to student learning, to exactly which components of the research environment bring about intellectual growth, or to which of these different components might be most crucial.

The NSF funded ePortfolio Project is a collaboration among several institutions. The project goal is to develop a more objective, evidence-based approach, than is currently available through surveys and standardized tests, to gain insight into student learning that takes place in a mentored research experience. To measure student intellectual growth the NSF ePortfolio Project has developed an evaluation tool to examine student research products before and after a research experience. The tool for this task is embedded in a learning portfolio, which documents *and* promotes learning (see Cambridge, Cambridge, Yancey, 2008 for numerous examples). A learning portfolio pulls together three domains: documentation (of



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research products); collaboration (the faculty/student research collaboration); and reflection (on the collaborative project that produces the products) (Zubizarreta, 2004). The Inter/National Coalition for Electronic Portfolio Research (http://ncepr.org/) provides a resource of projects from over 50 colleges and universities that document the connection between student learning and development, and the use of electronic portfolios. In this NSF project students set up electronic portfolios and add products from their research. Both students and mentors evaluate research products as matched pairs. The criteria used in the ePortfolio (ePort) to assess student intellectual growth are derived from the first three of IUPUI's Principles of Undergraduate Learning (PULs): (1) core communication and quantitative skills, (2) critical thinking, and (3) integration and application of knowledge (The IUPUI PULs, 2008). The American Association of Colleges and Universities (AAC&U) calls these "Essential Learning Outcomes" (AAC&U, 2007, listed on pg. 12). In the ePort, students and mentors access an evaluation tool, the "NSF Electronic Rubric", in order to assess skills reflected in research products that students have placed in their portfolios. At the end of the research project students respond to a mentoring survey to identify elements within the research environment and characteristics of the mentoring relationship that may have influenced their skills development. Both the research mentor and the student also fill out demographic surveys to help determine mentor/student characteristics that may influence the mentor/student collaboration and acquisition of skills. Reflections will ultimately provide further information about the collaborative experience. Note that data collected from both the mentor and the student can be quantified, stored in a database, retrieved, and matched between student and mentor.

Development and Evolution of the NSF Electronic Rubric (The Research Project Evaluation Tool)

The NSF Electronic Rubric is an undergraduate research assessment instrument, which has been constructed in an iterative fashion, for use across disciplines and with multiple undergraduate research products. Initially the primary objective was to design an evaluation tool to grade undergraduate research experiences, at first focused for use in the STEM disciplines, but then more broadly targeted for use across all disciplines. Eventually the objective was modified to *develop a rubric for rating research products*. Measurement challenges associated with rubric construction raise some basic questions: (1) What is a rubric and how is it defined in the literature? (2) How are rubrics developed and what do they look like? (3) Are there advantages or disadvantages to using rubrics? (4) Have relevant analytic rubrics, as envisioned for use in the NSF ePort, already been developed? If so, what do they look like? (5) Is it feasible to develop an analytic rubric across disciplines and multiple undergraduate research products? (6) Are there practical alternative approaches to the initial objective? And finally, (7) Are there recognizable criteria by which undergraduate research projects can be evaluated, and do those criteria reflect the selected learning outcomes of the PULs?

Definitions and Usefulness of Rubrics

Two definitions of "rubric" are useful in building a tool to evaluate undergraduates' research experiences and related products. A rubric:

- is a tool for assessing instruction and performance according to predetermined expectations and criteria (Taggert, Phifer, Nixon, Wood, 1998); and
- articulates in writing the various criteria and standards that a faculty member uses to evaluate student work. It translates informed professional judgment into numerical ratings on a scale. Something is always lost in the translation, but

the advantage is that these ratings can now be communicated and compared (Walvoord, 2004).

Discussions about rubric-related resources across disciplines frame rubrics as authentic assessment tools (for example, Taggert *et al*, 1998; Walvoord, 2004) that facilitate a student's thinking about criteria upon which work (including research products) may be evaluated. Additionally, rubrics make students aware of the criteria prior to receiving instruction and assessment.

Rubrics may be analytic or holistic, and task specific or general. *Analytic* rubrics provide specific feedback along several dimensions. Scoring is more consistent and provides more detailed feedback than *holistic* rubrics, but analytic rubrics are more time consuming. Conversely, holistic rubrics are useful for quick snapshots of student achievement, often providing a single score based on overall impressions of student performance on a task. They do not provide detailed information, and it may be difficult to provide one overall score. *Task specific* rubrics are used to assess knowledge when scoring consistency is extremely important, whereas *general* rubrics are used for assessing reasoning, skills, and products when all students are not doing the same task (Schreyer Institute for Teaching Excellence, 2008).

Alternate Approaches and Frameworks for Assessment

Initially the NSF ePortfolio project collaborators envisioned using an analytic rubric and attempted to construct a *task specific* rubric matrix. The matrix would be based upon three PULs that permeate the undergraduate curriculum and apply to undergraduate research activity. However, this type of rubric is very detailed and thus its specificity does not lend itself well to rating multiple types of research products from a range of disciplines. The overriding challenge associated with an analytic rubric for undergraduate research activities is that research mentors determine *specific* expectations for students with respect to their research project. In the NSF ePort the initial objective of rating diverse research products across disciplines intentionally required defining these expectations broadly. Analytic rubric construction requires making *specific* a *conceptual framework* that falls under the authority of each mentor and would require securing measurement criteria from all participants for each project. Because analytic rubrics are implicitly tied to single products or artifacts and therefore cannot be used across various disciplines or with multiple products, the NSF ePortfolio Project focused on the use of a holistic-generalized evaluation tool.

Identification and Evolution of Evaluation Criteria

The Intel International Science and Engineering Fair (Intel-ISEF) is the world's largest pre-college science competition. It provides an opportunity for young scientists from around the world to share ideas, showcase cutting-edge science projects, and compete for awards and scholarships (Society for Science and the Public, 2009). Criteria employed by Intel-ISEF to judge competitions were ultimately incorporated into the rubric-like ePort evaluation instrument. To construct a judging/scoring worksheet for student research projects, the University of New Mexico adapted assessment material from the Bay Area Science & Engineering Fair, BASEF-2002, which had originally adapted its judging criteria from those of the Intel's Science Fair (University of New Mexico Judging Rubric for Student Research Projects, 2004; see the judging form for BASEF 2002, http://hwhsef.mcmaster.ca/2002/judging/JudgingHandout2.doc). Using this adaptive approach the NSF ePortfolio Project built on the foundations of all three instruments and evolved five research themes: (1) design, innovation and/or solution; (2) thoroughness; (3) presentation; (4) approach and/or methodology; and (5) originality, in addition to learning outcomes associated with the PULs. Furthermore, there are elements associated with each of the themes that allow research mentors and students to rate the amount of evidence found in a product resulting from student undergraduate research.

The NSF ePort Evaluation Tool Design

The NSF ePort evaluation tool allows students and mentors to evaluate research skills on the basis of evidence they can recognize in products that are placed in the electronic portfolio. The tool asks evaluators to select the type of project approach from three choices: (1) *experimental approach*, an investigation proposed or undertaken to test one or more hypotheses; (2) *non-experimental approach*, a collection and analysis of data that is descriptive, observational, and/or showing evidence of a correlation or pattern of interest; and (3) *innovation or creative work*, the development and/or evaluation of models, innova-

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tions, or creative works. Evaluators must also consider at what level of originality a student is working and whether a project is being planned, executed or in completion. The type of product is selected from among the following choices: (1) abstract; (2) annotated bibliography; (3) lab report; (4) poster; (5) PowerPoint slides; (6) PowerPoint slides with narration; (7) research paper; and (8) scholarly works, as well a write-in category.

Integrating the NSF Evaluation Tool into the Electronic Portfolio

Once a hard-copy version of the evaluation instrument was developed it had to be integrated into a web-based electronic portfolio and made accessible to students at multiple universities for the NSF research project. The campus chose to utilize the Sakai ePortfolio. Originally conceived as a free alternative to commercial learning management software, the Sakai software is now in use in over 160 universities, colleges and schools throughout the world. Based on the "open source" development concept, the Sakai code can be deployed free of charge; moreover, institutions can suggest and develop additional software functionality, which in turn is added to the core programming infrastructure. The Sakai ePortfolio benefits from this community-based, open source approach, as new functionality is constantly under development (Open Source Portfolios, http://osportfolio.org).

As a founding member of Sakai, Indiana University -- and especially IUPUI -- plays a critical role in developing and implementing functional requirements to the ePort software. Over the last eighteen months, IUPUI has centered its ePort development on tools that allow for the direct gathering and assessment of student work. Specifically, the ePort "Matrix" tool illustrated on the web at http://crl.iupui.edu/NSFePortfolioProject/matrix.html allows for the visual presentation of student progress. The Matrix tool further enables both formative and summative assessment as it facilitates document workflow between the student and faculty mentor.

The NSF evaluation tool and other associated surveys were fairly complex. However, original ePort software was unable to gather and report anything but the most basic data. This challenge was met by using existing commercial survey software to construct the tools and surveys. Currently the project employs Checkbox, survey software distributed by Prezza Technologies. Students and mentors must link to the evaluation tool and surveys from a URL inside the portfolio until data gathering and reporting tools embedded in the ePort can be further developed. Student and mentor responses are stored in the survey tool's database until they are downloaded and transferred to ACCESS for additional analysis.

A range of data reporting functions that can be accessed directly from the ePort software are now under development. Once implemented, reports will allow for the querying of data across various Matrix cell/column/row combinations. Some of the quantitative, objective information gathered from student electronic portfolios is ultimately available to the institutions who may also be constructing institutional portfolios (iPorts) for assessment, as is the case at IUPUI (IUPUI Institutional Portfolio; http://www.iport.iupui.edu).

Selected information about the project and tools that were constructed can be viewed by accessing the following URLs:

- overview of the NSF project: http://crl.iupui.edu/NSFePortfolioProject/NSFproject.html;
- the NSF Undergraduate Research Product Evaluation Tool: http://surveycentral.uc.iupui.edu/nsfevalcur.aspx;
- the NSF Undergraduate Research Survey Regarding the Mentoring Experience: http://surveycentral.uc.iupui.edu/nsfmentoringcur.aspx.

Further development of the NSF research portfolio will improve and refine elements that complement the NSF evaluation tool including the introduction to the NSF project, instructions for using the site, relevant resources, and communication tools, as well as a robust set of prompts for self reflection related to the research and mentoring experience. The centerpiece of the site is a matrix consisting of cells where students can upload examples of products representing work from their pre- and post- undergraduate research experience. From this matrix students access the evaluation tool, a demographic survey, a survey regarding their relationship with their mentor, and several opportunities to provide reflective feedback. Mentors also can access and evaluate student work through this matrix. The tool also can assess students' research experiences over time since they can store work from the beginning and the end of projects as well as over the course of their undergraduate careers from early research participation until graduation.

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