What Research on Learning Can Tell Us about Undergraduate Research[1]:

Crossing Boundaries

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This paper grew from a paper presented at a recent Project Kaleidoscope conference at the University of Richmond[2]. On that occasion several speakers commented on the impact of the National Research Council book, *How People Learn*, a report on the cognitive science of learning. A digest of information resulting from research on learning, *How People Learn* examined the issues of preconceptions in learning, memory and transfer, and differences between novices and experts in science, Mathematics, and to a lesser degree, History. I was familiar with the book because Elaine Seymour and I had referred to it at the outset or our NSF/ROLE funded work on the assessment of the benefits of undergraduate research experiences in the sciences[3]. We noted that the book made these points:

- Children are active learners whose learning is motivated by a desire for mastery.
- How children learn is partially determined by what they already know, including schemes and perspectives they bring to new situations.
- Each child has a "zone of proximal development", a potential learning level beyond what they currently know. This zone may be assessed by showing the

[1] Presented at the 10th National Conference of the Council on Undergraduate Research, La Crosse, WI, 2004.

[2] PKAL assembly at the University of Richmond, October 29-31, 2003.

[3] *Pilot Study to Establish the Nature and Impact of Effective Undergraduate Research Experiences on Learning, Attitude, and Career Choice*. Funded as NSF/ROLE grant REC0087611.

child how to perform a task and then testing the child's ability to follow the example.

- Children learn best in a supportive environment. This environment includes mentors and peers.

- An important outcome of learning is transfer of training to new academic experiences and to everyday life.

Although most of the supporting research for these assertions was based on children, we proceeded to draw the analogy to the college student involved in undergraduate research:

- College students are active learners motivated by a desire for mastery. Part of this motivation is the desire to test themselves for professional careers. Career choice is a feature of their motivation.

- College student learning is partially determined by what they already know, however, the degree to which a curricular experience informs independent research is not known.

- A college student's potential may not be restricted to their prior classroom experience. College students may have a "zone of proximal development" which mentors intuitively assess when they choose research assistants.

- College students learn best in a supportive environment, which includes mentoring and peer groups, i.e., a community of learners.

- An important outcome of learning is transfer of training to a graduate education and to careers.

Our initial research on the undergraduate research experience involved a mixed qualitative and quantitative methodology aimed at delineating the benefits of the undergraduate research experience in the sciences. Seymour and her associates employed an interview protocol with student and faculty respondents. Interviews were conducted at four liberal arts colleges. Transcripts of each interview were carefully coded to yield the reported benefits of the UR experience. Coordinated with this work was a survey I devised that gathered quantitative information about the benefits of the URE at the same for research sites over a period of two years.

In a moment I will show you the results of these two efforts, and I will argue that the two sets of results may be linked to provide some confidence that we can enumerate the benefits of undergraduate research experiences. First let me make come comments regarding the relevance of our results to *How People Learn*. The survey results indicated that

- Students did value mastering their field of expertise. They rated learning a topic in depth and understanding the research process in their field as important and large gains.

- The data indicated that student benefited most when the mentor exhibited traits consistent with positive social interactions. They also benefited from working in teams.

- The data indicated that students who learned by example rated their satisfaction higher than other styles of learning, such as learning alone. The preference is consistent with the notion of the zone of proximal development.

In other words, the undergraduate research experience is consistent with the ideas expressed in *How People Learn* – as far as it goes. But a closer look at the book revealed a gap in our understanding of *How People Learn* and how students learn in the UR experience. As I reported at Richmond, it is necessary to describe our findings in order to understand the gap.

The Benefits of the Undergraduate Research Experience

Seymour et al. (2004) interviewed 76 students who had participated in undergraduate research experiences in the sciences at one of four liberal arts colleges. The interviews were transcribed and coded for reports of the benefits of undergraduate research experiences. A summary of her final "parent codes" is presented in Table 1.

The findings summarized in Table1 illustrate that both the learning and changes in attitude that are taking place during the undergraduate research experience. Specific skills are being learned and enhanced, competency is being established, and a transformation from novice to expert is taking place. These three topics – skill learning, competency motivation, and expertise – are discussed in *How People Learn*. But there seems to be an additional developmental aspect to the experience that is not extensively treated in the book. Before I focus on that developmental aspect, however, let me present findings from the quantitative half of our research collaboration that might help validate these categories of benefits.

By drawing on the literature of purported benefits of undergraduate research and by receiving early reports of Seymour's findings, I was able to construct a survey instrument for students doing undergraduate research at the same four liberal arts colleges where Elaine had interviewed. In each of two summers students in the sciences filled out an extensive survey. Some items asked about the topics mentioned earlier in this paper; more pertinent is the fact that the surveys contained a list of 45 possible benefits of undergraduate research. Each student respondent was asked to rate his or her gain on the benefit on a scale of 1 (no or little gain) to 5 (Very large gain). A large data set (N = 384) yielded a wealth of information on the various questions. A more restricted data set (N = 181), consisting of those respondents who rated every one of the 45 benefits, was employed to perform an exploratory factor analysis to construct the dimensions that might organize the 45 benefit variables. Exploratory Factor Analysis is a statistical procedure for quantitative data and so is a very different methodology from coding qualitative data, as Seymour, et al., did. Nevertheless, because the two studies drew from the same kind of experience (summer undergraduate research) at the same four research sites we hope to see some congruence between the qualitative codes and the quantitative factors. By finding agreement between two attempts using different methods to measure the same benefits, I hope to establish the validity of the findings.

The results of the factor analysis are presented in Table 2. The ten factors are selected because they each meet a conventional criterion of accounting for more than one original variable. The ten factors together account for 66% of the variance in the data. The factors are named by the analyst, who inspects the variables that correlate with (or load on) the factors. Table 2 shows my names for the factors together with the variables with the strongest loadings (only loadings of .4 or better are shown).

Comparing the statistical analysis in Table 2 to the earlier coding analysis in Table 1, we notice that there are 10 factors versus 7 categories. This difference does not prove to be a serious difficulty, however, if we notice that Seymour, et al., coded a "skills" category that was generic. The factor analysis, on the other hand, broke out several categories of skills, reflecting the underlying pattern of correlations. Allowing for the difference in number of categories, I proceed to line up the two analyses in Figure 1. In order to judge the alignment, the reader should look back at Tables 1 and 2, and based on the similarity of the concepts that go into a code category (or the survey items that load on a factor) judge the congruence between the two sets of findings. I found a high degree of linkage between the qualitative and quantitative results, with only a few qualifications. First, as I mentioned, the qualitative "skills" category incorporates five of the factors, all of which are specific sorts of skills. Second, one of the qualitative categories, a small category called "other benefits", has no corresponding items in the survey. Finally, one of the factors, called "interaction/communication skills", overlaps with two of the qualitative categories. While some of the items that make up the factor are clearly skills, at least one item, "learning to work independently", also coheres with the qualitative category "changes in attitudes toward learning and working as a researcher". All in all, it is my belief that the results of the two methods map onto each other well.

Both the qualitative and quantitative analyses suggest a developmental dimension of learning for which undergraduate research experiences may set the occasion. Students report a rich mixture of personal and professional development that may help us understand the concept of expertise. *How People Learn* treats expertise as cognitive; experts exceed novices in chunking relevant information and contextualizing knowledge. But expertise may also include the acquisition of independent thought and the motivation to pursue new regions of knowledge based on a belief about the value of that knowledge. This belief, perhaps no more than a hunch, becomes a strong source of motivation to continue working in the face of obstacles, skepticism, and opposition. In other words, experts learn commitment. This aspect of learning is the gap between *How People Learn* and how people learn in undergraduate research.

Intellectual Development in Undergraduate Research

William Rauckhorst presented a paper at a 2001 PKAL conference based on the work of Marcia Baxter Magolda. Baxter Magolda had assessed summer research students with an instrument she devised called the MER (Measure of Epistemological Reflection). This measure permits the researcher to categorize the student's epistemological level. According to Baxter Magolda, student intellectual development follows a series of stages. These stages are summarized in Table 3[4]. The table is a mere outline; it does not do justice to the richness of the theory. But it can be seen that each stage represents a more sophisticated level of understanding than the previous one. Rauckhorst reported that, based on MER scores, students who had a summer undergraduate research experience showed more frequent transitions up the stages than students in a control group. For example, fourteen of 35 initial transitional knowers among research students shifted up to independent knowers at the end of the summer. In the control group, none of the 31 initial transitional knowers showed any shifting up the developmental ladder.

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[4] For a summary of Baxter Magolda's theory and contemporary theories of intellectual development, see Evans, N.J., Forney, D.S., & Guido-DiBrito, F. (1998). *Student development in college*. NY: John Wiley and Sons.

The possibility that the benefits of undergraduate research may be measured by the intellectual development of the student is intriguing, but being something more than absolute knowers ourselves, some undergraduate researchers and I explored this area of research in the summer of 2003[5]. Using information from Baxter Magolda supplemented by the work of King and Kitchener (1994) on reflective judgment, we prepared an interview protocol that provided respondents an opportunity to tell us something about their thinking on controversial issues. Forty-two students working on summer research projects for a 10-week period were interviewed early and late in the summer. We discovered that coding the student responses into categories of development is hard work; students often make a series of responses that cross categories. Nevertheless, we were able to form a consensus about placing each student respondent into a pretest category and a posttest category that roughly conformed to the Baxter Magolda levels. We placed 16 students into the absolute/transitional range, 20 students into the transitional/independent range, and 6 students into the independent/contextual range. Posttest classifications showed that 12 of the 16 students in the lower range on the pretest moved up the scale on the posttest; 9 of the 20 mid-range students moved up; while none of the 6 students in the top range moved. Twelve of the students were not in the sciences; they showed the same patterns as the science students.

I freely admit that my students and I are amateurs when it comes to coding interview data into stages of intellectual development. I also admit that, unlike Rauckhorst, et al., we had no control group. We were attempting to "acquire conviction" about this sort of research before accepting it. I am convinced that, despite the methodological difficulties, it is a line of research worth pursuing.

It seems that the undergraduate research experience ignited "a bright period of maturation" (Lopatto, 2002). According to Baxter Magolda (2001) the goal of this maturation is "self-authorship", which includes reflection on epistemology, but also the discovery of self and the choosing of beliefs. Within the context of developmental theories like this one, expertise is not defined solely by cognitive capacity, as it seems to be in *How People Learn*, but includes self-knowledge and beliefs to which one becomes

[5] I am indebted to Sarah Clark, Martha Bibb, Becca Schmidt, and Zach Dewitt for their help with this research.

committed. Thus developmental theories attempt to describe not just how people learn but why people learn.

Crossing Boundaries

Now I come to a turn in the road that I did not take in the earlier paper. I concluded the earlier paper by extolling the benefits of the undergraduate research experience in the development of intellect, but I did not comment on disciplines outside the sciences. I take up the topic of undergraduate research outside the sciences because I believe that the developmental aspect of undergraduate research provides a link across the boundaries of the disciplines that *How People Learn* does not. *How People Learn* is silent on how people learn in the social sciences and humanities, except for a sliver of information regarding History. The omission seems strange. After all, the book is not called *How People Learn Science and Math*. But let us pursue the assertion I made a few sentences ago, namely, that expertise is not defined solely by cognitive capacity but includes a developmental dimension including personal, intellectual, and professional gains. I have asserted that these gains can be seen in the study of undergraduate research in the sciences. If only we had some data from undergraduate research experiences in nonscience disciplines, perhaps we could say something about how people learn instead of how people learn in science and math.

The happy fact is that I have been collecting data over the past few years from undergraduate researchers from social science and humanities. I have survey data from 73 students who participated in summer research programs at two liberal arts colleges (Table 4). It is a much smaller sample than the science students, but perhaps we can compare what we find with the science students. The question is, with respect to the experience of and benefits from the undergraduate research experience, are there parallels between the science and nonscience students?

Here, in summary form, are some comparisons between the data from 384 science students and 73 nonscience students, all taking part in summer UR experiences. The nonscience students are from two of the four science research sites.

- Science students report a variety of weekly contact hours with their faculty mentors. These weekly contacts ranged from 15 hours (Chemistry) to about 6 hours (Math, Computer science). The overall mean weekly contact hours for the nonscience students is 6.7 hours, with social science groups having more contact (Psychology = 7.8, Sociology = 9.0) and the humanities groups have less contact (Theater = 3, Music = 2.3).

- Availability of the mentor is high in both the sciences and the nonsciences. Ninety-two percent of science students reported that their mentors were available more than half the time or always. Eighty-three percent of the nonscience students report that their mentors were available more than half the time or always. For both groups, availability correlates directly with overall satisfaction (science $r_s = .17$; nonscience $r_s = .36$).

- Fifty-eight percent of the science students reported that their project was assigned by the mentor. Only 30% of the nonscience students reported this. Forty-two percent reported that they worked with the mentor to design the project. Unlike the science students, nonscience students did not report a difference in overall satisfaction based on this distinction.

- The most common style of structure setting was "a rough schedule to meet goals" (38% of the science students). This structure was the most frequently reported among the nonscience students (46%).

- The most common style of interaction between student and mentor was "learning by example" for science students. For nonscience students, the most common style of interaction was "self-organized" (41%). The nonscience students reported significantly less satisfaction in the "self-organized" group ($\underline{M} = 4.0$) than in other interactional styles. The mean, however, is high in absolute terms (the scale runs from 1 to 5).

- While only 19.5% of the science students reported working alone, 58% of the nonscience students reported working alone.

- Student ratings of mentor traits are parallel (Table 5). Among the science students, it was reported that mentor traits correlated with student satisfaction and with the benefit called "Developing a continuing relationship with a faculty member". The data from the nonscience group also shows some correlations of this sort, but the number of respondents is relatively small so I interpret this finding with caution.

- On the topic "Developing a continuing relationship with a faculty member", nonscience students report at least as much gain on this benefit as science students (Table 6).

Students not in the sciences have fewer contact hours with mentors, work alone more often, develop their own projects more often, and have less structure to their experience than their science colleagues. Nevertheless, they think highly of their mentors and develop a relationship with them. In addition, the nonscience students evaluate their learning gains in a similar way to science students (Tables 7 and 8). Both groups cite gains in learning in depth, enhancement of credentials, and readiness for more research. With respect to intellectual development, I refer the reader back to the earlier section of this paper. To reiterate, twelve of the students were not in the sciences; they showed the same patterns as the science students. My conclusion is that while undergraduate research experiences may be very different in their disciplines, there are personal, intellectual, and professional gains common to them all.

Why people learn

It may be that our desires for mastery, for maturation, and for "self-authorship" are intrinsic. In my earlier paper I found it useful to cite the words of Sharon Daloz Parks (2000), who suggested that young adults are engaged in "probing commitment", a tentative attempt to discover truths that may be held in a contextual world. If successful in this endeavor the young adult may grow to have a "confident inner-dependence" meaning that one is able to "include the self within the arena of authority". Undergraduate research provides the arena for learning how conviction is acquired and for finding the confidence to make a commitment to both a truth and a vocation.

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Table 1. Summary of the seven benefit categories presented by Seymour et al. (2004)

Personal/professional	Increased confidence in ability to do research and other tasks; feeling like a scientist; working relationships
Thinking and working like a scientist	Application of knowledge and skills; increased knowledge and understanding of science and research work
Skills	Improved communication, lab/field techniques, work organization, computer, reading, working collaboratively, information retrieval
Clarification, confirmation and refinement of career/education	Validation of disciplinary interests; graduate school intentions; increased interest for the field
Enhanced career/graduate school preparation	Authentic research experience; opportunities for collaboration/networking; resume enhanced
Changes in attitudes toward learning and working as a researcher	Undertaking greater responsibility for project; increased independence; intrinsic interest in learning
Other benefits	A good summer job; access to good lab equipment

Table 2. Summary of the 10 factors resulting from survey data on benefits of undergraduate research experience.	
Interaction and communication skills	Skill at oral, visual, and written communication; leadership; becoming part of a learning community; working independently; ability to collaborate with other researchers
Data collection and interpretation skills	Ability to collect data according to a plan; ability to analyze data; skill in interpretation of results; lab techniques; ability to solve technical or procedural problems
Professional development	Understanding professional behavior in your discipline; understanding personal demands of a career in your discipline; understanding the research process in your field; understanding how professionals work on real problems
Personal development	Sense of accomplishment; tolerance for obstacles; self-confidence; interest in a discipline
Design and hypothesis skills	Ability to employ appropriate design methods; ability to integrate theory and practice; critical evaluation of hypotheses and methods in the literature
Professional advancement	Opportunities for publication; sense of contributing to a body of knowledge; opportunities for networking; enhancement of your professional or academic credentials; developing a continuing relationship with a faculty member
Information literacy skills	Ability to read and understand primary literature; ability to locate and identify the relevant literature; ability to see connections to your college course work
Responsibility	Learning safety techniques; learning the ethical standards in your field
Knowledge synthesis	Learning a topic in depth; understanding how current research ideas build upon previous studies
Computer skills	Computer skills (either user or programmer)

Table 3. Stages of college student intellectual development (Baxter Magolda.)	
Absolute knowing	Knowledge viewed as certain; authorities have the answers
Transitional knowing	Some knowledge is uncertain; find processes to search for truth
Independent knowing	Thinking rather than accepting views is important; individuals may have their own beliefs
Contextual knowing	The legitimacy of knowledge is contextual; perspectives require supporting evidence

Table 4. Areas of research reported by the nonscience students.

Area	**Frequency**
Anthropology	12
Chinese	1
Economics	6
Education	4
History	3
Information Services	1
Music	3
Philosophy	2
Political Science	7
Psychology	16
Religious Studies	3
Russian	1
Sociology	12
Theater	2
Total	73

Table 5. Ratings of mentor traits (1 to 5 scale) by science and nonscience students.		
Mentor Trait	**Mean rating**	
	Science	Nonscience
Friendly	4.55	4.47
Reliable	3.26	3.26
Respectful	4.45	4.42
Organized	2.80	2.81
Democratic	3.93	4.12
Communication	3.04	3.10
Responsive	3.54	3.45
Colleague	4.10	4.26

Table 6. Response distribution for rating gains in developing a continuing relationship with a faculty member.		
Item	**Frequency (%)**	
	Science	**Nonscience**
Very small gain	10 *(2.6%)*	1 *(1.5%)*
Small gain	36 *(9.4%)*	3 *(4.4%)*
Moderate gain	92 *(24.1%)*	15 *(22.1%)*
Large gain	118 *(30.9%)*	16 *(23.5%)*
Very large gain	125 *(32.8%)*	33 *(48.5%)*
Total reporting	381	68

Table 7. Social science and humanities student responses to the instruction to assess their gains in 45 areas on a scale of 1 (no gain) to 5 (very large gain) after an undergraduate research experience. Students rated 45 possible benefits. The 10 top rated benefits are shown here with mean ratings in parentheses. 73 students took part in the survey. The stem sentence was “From your research experience how much of a gain occurred in …”

Learning a topic in depth (4.26)
Opportunities for poster or oral presentations (4.18)
Developing a continuing relationship with a faculty member (4.13)
Understanding the research process in your field (4.03)
Enhancement of your professional or academic credentials (4.03)
Readiness for more demanding research (3.97)
Ability to analyze data (or information) (3.93)
Ability to collect data (or information) according to a plan (3.87)
Sense of contributing to a body of knowledge (3.79)
Sense of accomplishment (3.76)

Table 8. Science student responses to the instruction to assess their gains in 45 areas on a scale of 1 (no gain) to 5 (very large gain) after an undergraduate research experience. Students rated 45 possible benefits. The 10 top rated benefits are shown here with mean ratings in parentheses. 384 students took part in the survey. The stem sentence was “From your research experience how much of a gain occurred in …”

Learning a topic in depth (4.10)
Laboratory techniques (or field techniques) (3.96)
Enhancement of your professional or academic credentials (3.94)
Understanding the research process in your field (3.94)
Opportunities for poster or oral presentations (3.89)
Learning to persevere at a task (3.85)
Developing a continuing relationship with a faculty member (3.82)
Understanding of how current research ideas build on previous studies (3.70)
Readiness for more demanding research (3.68)
Skill in the use of instruments (other than computers) (3.63)

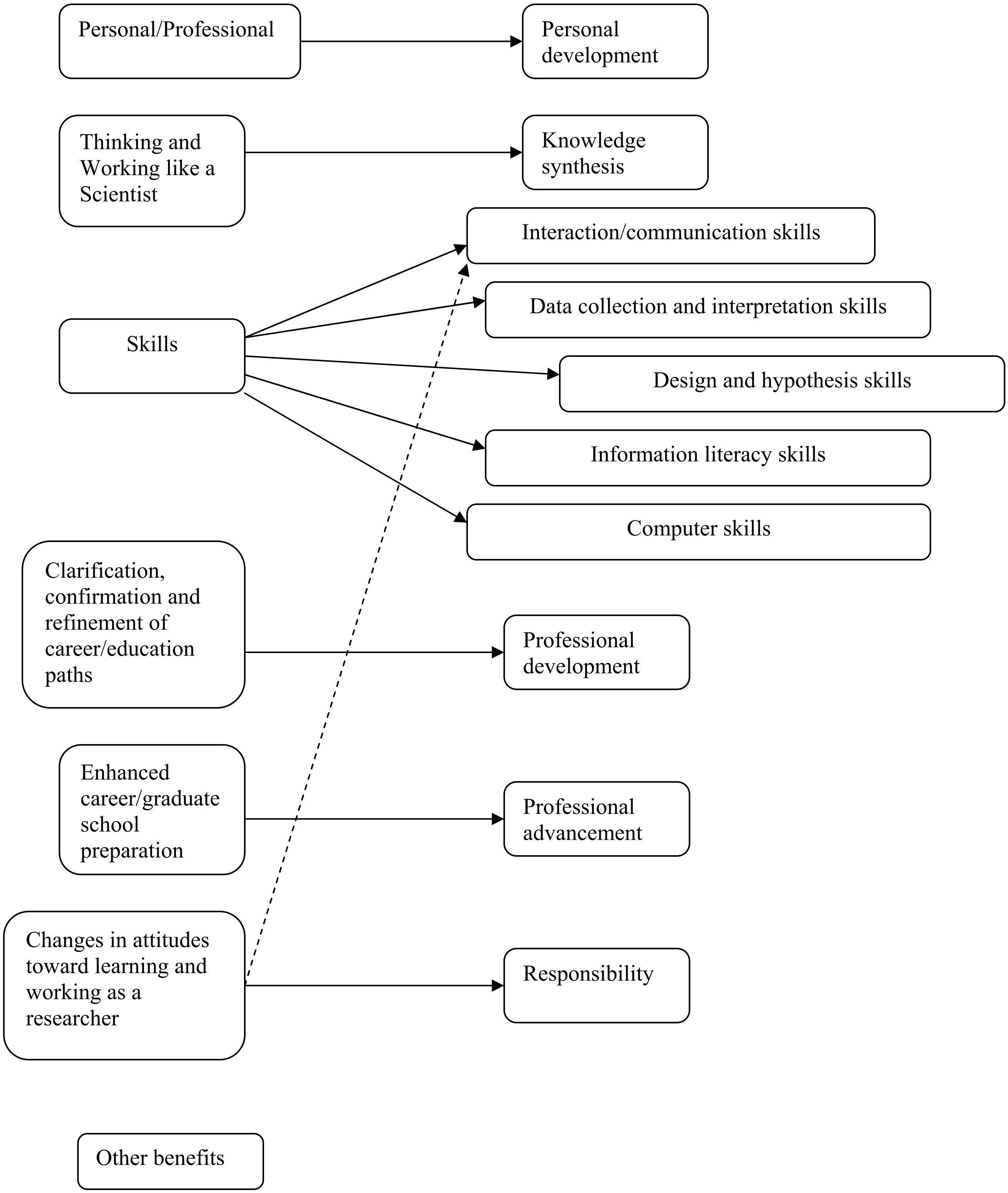

Figure 1. An attempt to align the seven parent categories of student benefits found by Seymour et al. (*left*) with a factor analysis of survey data on student benefits (*right*).