Undergraduate research under the microscope – contrasting the focus of academics and students

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Abstract

Undergraduate research, inquiry and problem solving experiences are increasingly used to stimulate student understanding of the practice of science. We propose that such experiences not only play an important role in student acquisition of skills and understanding of scientific processes, but also encourage broader learning outcomes. However academics may not be fully aware of these more generic gains. In this study within a science department at a large metropolitan research intensive university, we interviewed academics and surveyed students to examine the learning gains from undergraduate research opportunities as perceived by the two groups. Interviews with academics highlighted a strong culture of integrating research and inquiry into teaching, with intended gains being research skills and encouraging students to think like scientists. Students reported learning gains to be problem solving skills, data collecting, and working collaboratively. These later "personal gains" reported by students were not identified by academics. We believe the difference between students and academics could reflect an under-valuing by academics of the broader impacts of research and inquiry on student learning. The findings of this study have implications for the ongoing support of undergraduate research and inquiry, and its growth as a valuable learning experience in the tertiary science curriculum.

Introduction

Quality indicators, competencies and measurable graduate outcomes increasingly define higher education. Undergraduate research (UR) or 'inquiry' experiences are accepted as representing high impact learning opportunities (Kuh 2008) which enable the development of measurable graduate outcomes in: critical thinking, thinking and working like a researcher, and application of knowledge and skills (Hunter, Laursen and Seymour 2007). However, those graduate outcomes are rarely considered in the context of the benefits *intended* by the academics who include UR in their teaching. Are those intended benefits realised in students' experiences, or are there discrepancies between the academics' intentions and the benefits that students actually report through their UR experience?

While student learning benefits from UR have been widely documented, the perspectives of the academics teaching them are seldom heard. This study seeks to redress that balance and describe the views of seven academics. To do this we first consider the definitions of UR and describe the benefits of students undertaking UR experiences in a research-rich, science learning environment. Second, we compare the benefits intended by the academics with the benefits actually reported by their students. We identify the similarities and differences between academic and student perceptions, including possibly conflicting viewpoints.

Definitions and frameworks of undergraduate research

In this study, we initially defined UR using the American Council for Undergraduate Research (CUR) definition:

> *'An inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline.'* (Beckman and Hensel 2009; p.40.)

Prior to the CUR definition, Healey and Jenkins (Healey 2005; Healey and Jenkins 2009) provided a broader definition for viewing student engagement with research and inquiry. Their definition included a framework describing student research and inquiry opportunities inside and outside the curriculum, with a range of activities which could be viewed as 'research'. This conceptual framework (Figure 1) underpins our study. It provides a broad mapping of diverse research experiences and includes both *passive* (students as audience) and *active* (students as participants) experiences. The framework clearly positions inquiry-based learning in the research-based learning quadrant. This framework has been used successfully in previous studies of UR (see Elsen, Visser-Wijnveen, van der Rijst and van Driel 2009; Ozay 2012; Zimbardi and Myatt 2014).

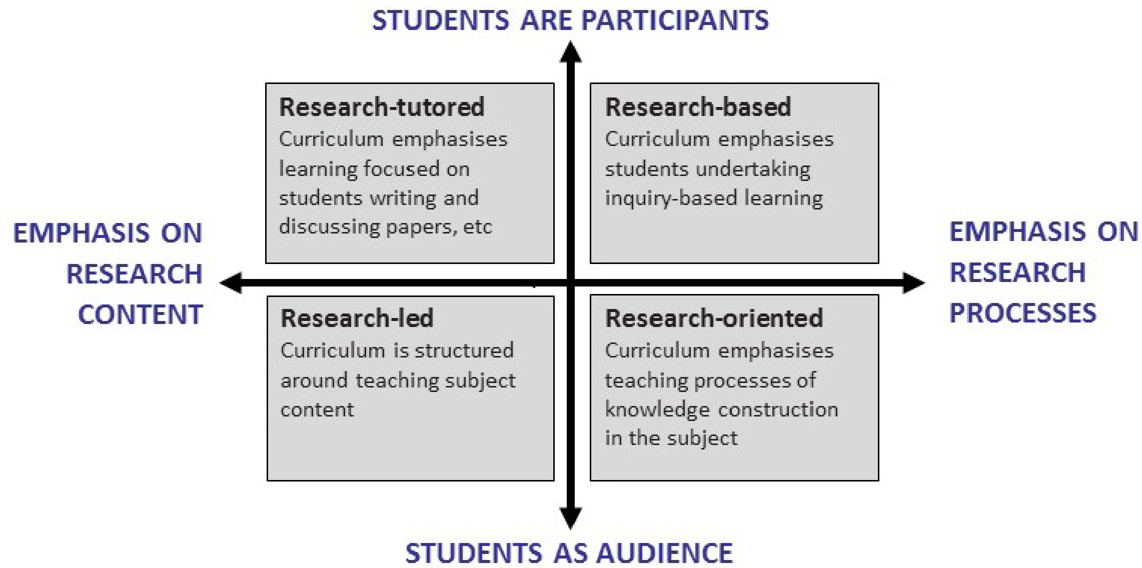

Figure 1. A framework to examine the diversity of activities defined as "undergraduate research" (from Healey 2005).

The tension on how UR can be defined was acknowledged by Brew (2010) who proposed an extension to the CUR definition that allowed the inclusion of research-based activities and a wider understanding of knowledge production – specifically, to include knowledge that is new to the student. She proposed that UR was:

> [An] inquiry or investigation *or a research-based activity* conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline *and/or to understanding* [italics added].
> (Brew 2010; following Beckman and Hensel 2009, additions in italics)

Beckman and Hensel (2009) argued that because of the tensions arising from their definition, institutions need to create their own definitions for UR. We adopted the definition from Brew (2010), and focussed on a subset of *active* research experiences (Healey 2005). We define UR as including activities in which the students uncover knowledge that is new to them, although not necessarily new to the discipline. We consider that the student's learning gains are dependent on a combination of features - the scientific authenticity of the task, the student's sense of ownership of the project and the student's independence in performing it. This is consistent both with Brew's modified definition (Brew 2010; Brew and Jewell 2012) and a broad approach to research skill development (Willison and O'Regan 2007).

Benefits of undergraduate research

A broad set of benefits from UR in terms of "students' engagement in authentic research" are widely reported in the sciences (Laursen, Hunter, Seymour, Thiry and Melton 2010; p33). The early work of Seymour and colleagues (see Seymour, Hunter, Laursen and Deantoni 2004) set a benchmark for researching and analysing these benefits and gave impetus to the detailed examination and evaluation of UR student experiences. Their multi-year research of summer undergraduate science researchers in four liberal arts colleges, classified student gains into several broad categories (Seymour et al. 2004). Lopatto (2004), with survey data from more than 1000 students at the same four liberal arts colleges used in Seymour's work, further confirmed the gains associated with UR. Hunter et al. (2007) expanded this to compare the perspectives of faculty and students. They described six major benefits: personal/professional gains (such as increased confidence), intellectual gains (also termed "thinking and working like a scientist"), gains in skills (including technical and communication skills), gains in professional socialisation (termed "becoming a scientist" and including professional practice); clarification/confirmation of future career plans; and enhanced preparation for career/graduate research.

The research-focussed benefits from UR have been shown to be widespread and substantive (for an overview of literature see Laursen et al. 2010; and examples such as: John and Creighton 2011; Myatt 2009; Russell, Hancock and McCullough 2007). However there have been calls to acknowledge the role of research experiences in developing broader skills – such as those identified as necessary for our 21st century graduates, who will be required to identify and critically analyse problems and develop creative solutions in an increasingly changing world. Many authors now make direct links between research experiences and the development of higher order skills such as critical thinking (Leggett, Kinnear, Boyce and Bennett 2004), critical inquiry and creativity (Brew 2006; Brew 2010) and graduate attributes (Kuh 2008). In particular, Ronald Barnett (2004), when writing of "Learning for an unknown future", cautioned us to think further than just the development of transferable (generic) skills for students and challenged academics to promote learning in terms of "human qualities and dispositions" in light of a complex and uncertain future. He challenged academics to design learning activities that were both high risk and transformative in character – encouraging students to engage as themselves and not just as 'knowers of the discipline'. Barnett was not writing specifically about UR experiences and yet his words parallel with the literature on student learning through research. He speaks of authentic pedagogical tasks and downplays the importance of knowledge and skills acquisition without context. Barnett's vision of effective curricula, of preparing students for the future, mirrors UR and inquiry experiences and their powerful role in enhancing student learning.

Research question

This study examines the broad research question: are the benefits from undergraduate research experiences reported by students different from those intended by the academics? Specifically we ask: what benefits do academic staff believe their students gain from UR? What benefits do students actually report? What does a comparison of these views reveal?

Methodology

Context

The learning context was a large metropolitan research intensive Australian university rich in opportunities for students to be involved in active authentic UR experiences (Jones and Myatt, 2010). Active authentic research opportunities were identified both inside and outside the curriculum: some were voluntary, but most activities were embedded within units and linked to compulsory assessment tasks. This provides evidence of a learning context rich in intended undergraduate research experiences. While a wide range of experiences may be considered as UR, we focussed only on the forms of research in which the students are active participants – whether in the field, the laboratory or in the library, focussing on writing about or discussing the research of others, or undertaking their own research projects.

Approach

The study took a qualitative approach, with a constructivist perspective as defined by Creswell (1994, p.21). The external peer reviewer (Myatt) was given access to teaching materials, including unit outlines and examples of assessment tasks, for all relevant units (= subjects) taught by the School. Academic staff responsible for developing and teaching these units were interviewed. An analysis of the interviews compared to a survey of students forms the basis of this paper. Institutional ethical clearance (H11157) was obtained for this study.

Staff interviews

Seven academics were interviewed for one- two hours, using a semi-structured technique with prepared questions. Each interview was recorded, transcribed and analysed (see analysis section). The questions were on the specific UR activities for which academics were responsible. As part of the interviews, the project's definition of "undergraduate research" was described and academics teaching and learning activities discussed. The academics were asked to describe what their students did, and how they benefitted. For example: "What do you believe are the benefits your students gain from their undergraduate research experience?". Academics described the details of their UR activities, provided insights into their motivations for UR and described the expected outcomes from UR for students.

Student survey

We used a modification of the online URSSA (Undergraduate Research Student Self-Assessment) survey instrument to investigate student-identified gains and experiences as developed by Hunter, Weston, Laursen, and Thiry (2009), University of Colorado, Boulder. The URSSA survey is structured around clear categories of benefits for students including: personal/professional, thinking and working like a scientist, skills, becoming a scientist, career clarification, and enhanced career preparation (Seymour et al. 2004; Hunter et al. 2007). The modified survey was shorter than the original, with several sections removed for brevity, some specific items that were not relevant to the context were deleted, and some word changes were made to reflect specific university terminology. Using an adapted URSSA survey reduced the quantity of data obtained but did not alter the integrity of the data. The survey contained two types of closed response questions: type 1 provided a list of statements and respondents selected any that applied to them; type 2 provided a list of statements and respondents indicated on a 5-point Likert Scale the degree to which they were 'satisfied' or the degree to which they 'gained'. A link to the survey was emailed to 335 students enrolled in units identified as incorporating UR, with 42 de-identified responses received.

Implications arising from the method

It is important to note some specific caveats arising from the method. In the online survey, students were asked about specific "gains", such as direct questions on how much they gained in "confidence to undertake research" and how much they gained in "comfort in working collaboratively with others". In contrast, the staff interviews, whilst using guided questions, were not specifically prompted. The academics were asked questions such as: "What do you most want students to gain?" and "What longer-term consequences do you predict for students with UR experience?"

It is also important to note the small sample size of student responses to the survey. Of the 335 students invited to participate in the survey, only 13% responded (n=42). This small sample may not fully represent the views of the whole student population: for example students with a positive or negative experience may be over represented. Furthermore, the necessary changes to the instrument mean that comparisons of our data with previous (or future) work using the original URSSA survey are possible but must be made with care.

Analysis

The transcripts of interviews with academics were read to identify the benefits gained by students. The analytical framework used to guide the coding (see Table 1) was derived from previously reported categories (Hunter et al. 2007): personal/professional gains, "thinking and working like a scientist", skills, becoming a scientist, career clarification, and enhanced career preparation. All references to student benefits could be matched to these six categories.

The process of coding was carried out by an objective academic not associated with the curriculum (Myatt). Each transcript was coded twice. Themes relating to the identification of student benefits were identified in each independent coding. The cross-checking of the coding process ensured identification of all benefits and increased consistency. To allow a comparison between student benefits from UR as reported by academics (qualitatively) to the outcomes reported (quantitatively) by the students, the benefits identified by academics were also tallied providing a quantitative measure of qualitative responses. (see Table 1 Legend).

The quantitative data from the student survey were analysed as percentages of total responses. Each survey question dealing with "student gain" comprised a varying number of smaller items. The mean for each question was calculated using the responses to all items within the question. The major categories were matched with the core categories of questions within the URSSA survey (Hunter et al. 2007). In our modified URSSA survey, those core categories were retained, thereby offering a structural similarity between the codified data from the interviews (coded using six benefits categories) and the structure of the URSSA survey (with questions grouped within the same six benefit categories).

Results and discussion

Staff interviews – identification of anticipated student gains from UR activities

Analysis of the interviews with academics (see Table 1) revealed that more than 60% of the comments regarding student gains fell into two categories: "Thinking and working like a scientist" (34%) and "Skills" (31%). The gains reported in these categories were clearly disciplinary (i.e. scientific) gains. "Thinking and working like a scientist" includes gains in understanding of how scientific research is carried out, gains in intellectual growth and the ability to apply knowledge and skills. The "Skills" category relates to gains in laboratory, field, organisational and other skills.

Table 1. Student learning gains from UR as reported by academics (via interview) and by students (via online survey)

Category of student gains	% as reported by academics [A]	% reported by students [B]
1. Personal/professional (e.g. increased confidence in ability to do research, contribute to science, "feel like a scientist", establishing collegial relationships.)	8% (4 comments)	98% (40 students) (mean of 4 items)
2. Thinking and working like a scientist (e.g. Application of knowledge and skills, gains in critical thinking/problem solving, analysing, interpreting results, increased knowledge and understanding of science and research work.)	34% (21 comments)	100% (42 students) (mean of 5 items)
3. Skills (e.g. communication skills, laboratory/field techniques, work organization, working collaboratively, information retrieval.)	31% (18 comments)	96% (41 students) (mean of 14 items)
4. Becoming a scientist (e.g. student takes "ownership" of project, responsibility, initiative, understanding the nature of research work and professional practice.)	10% (8 comments)	100% (42 students) (mean of 4 items)
5. Career clarification (e.g. validation of disciplinary interests and clarification of future plans.)	8% (5 comments)	not analysed
6. Enhanced career preparation (e.g. real-world work experience)	8% (5 comments)	not analysed

[A] Values derived from interview data. All benefits identified by each academic were noted. In total, 7 academics described 61 benefits. Each benefit was allocated to a category using the categories devised by Hunter et al. 2007. Each cell indicates the number of benefits reported within that category and the percentage this number represents of the total number of benefits reported (%).

[B] Values derived from the online survey. Each cell indicates the mean number of students who indicated a gain (N) and the percentage of total respondents to that question (%). Each question dealing with "gain" was comprised of a varying number of smaller items. The question mean was calculated using responses to all items within the question. The number of items in each question is indicated in parenthesis.

Academics gave responses such as:

> "*There's the **actual doing** part, so the students are **getting experience** with firstly the equipment, so traps, cameras and line transect equipment, GPS. Many of the students haven't had experience…*" (Category 2: Thinking and working like a scientist; Category 3: Skills)

> *"So I think the benefit… is the students get to sit down and think about how do we actually address this question. Thinking in terms of replication, what form the data's recorded, how it's going to be analysed*." (Category 2: Thinking and working like a scientist)

Whilst commenting on these student gains, academics' comments would sometimes overlap with gains in the category "Becoming a scientist".

> "***Critical thinking** is the main thing. Because they've got **ownership** of what they're doing - so when something goes wrong, or they're missing a bit of information, or they see a hole in the design, then all the pieces start slotting together. They get a better appreciation of what the actual process of **doing an investigation** entails."* (Category 2: Thinking and working like a scientist; Category 4: Becoming a scientist)

> *"I guess … research experiences are all about teaching students that **science is open ended**, and research is open ended. **There isn't a correct answer** at the end. You can do the trial, and it opens up more questions."* (Category 4: Becoming a scientist)

In contrast, far fewer gains in the category "Personal/professional" were reported, with only three academics (of the seven) making four comments (of the 61) relating to student gains in this area.

> *"…by students actually holding on to things and measuring things, they actually become more confident in "Yes I can go out and collect data, collect measurements, record all those sorts of things"*. (Category 1: Personal/Professional)

The terms "trust", "ownership" and "being a scientist" are key characteristics of the category "Becoming a scientist" and are found cited in the literature (see Seymour et al. 2004). One academic commented:

> "*What do they actually get? I think the chief benefit is that they are given **trust**. They take **ownership** of something. It's their first taste of **being a scientist**."* (Category 4: Becoming a scientist)

Hearing academics articulate these terms during these interviews reaffirm the relatedness of the literature to our own context. Indeed, Laursen et al (2010) reported academic research advisors as more likely to report student gains in "Becoming a scientist" than students report themselves. Experienced academics recognise this professional socialisation and development of new behaviours. In this study, however, "Becoming a scientist" did not feature strongly as a category of expected gains.

In this study 31% of the comments related to gains in "Skills" (Table 1), but this same category accounted for only 8% of comments from advisors in Laursen (2010). This difference may be explained due to the different UR models examined. Laursen (2010) focussed on the 'summer research project' model where students conduct a broad project in a laboratory for several months, and such a model may not focus directly on specific skills development. The academic staff in our study coordinated UR experiences embedded in the core curriculum, and therefore skills development was a specifically desired, and often assessed, learning outcome within that curriculum.

Student surveys – identification of student gains from UR activities

As outlined previously, the online URSSA survey is structured around six categories of benefits (Seymour et al. 2004; Hunter et al. 2007; Laursen et al. 2010). In our survey, students overwhelmingly reported gains from their research experiences. Almost all students reported gains in almost all of the items in all of the relevant questions (see Table 1).

For the survey question examining gains in “Thinking and working like a scientist” (including items such as: “understanding how research is done”, “understanding how to collect scientific data” and “problem solving in general”), 100% of the students reported that they had made gains as a result of their UR experience. In the survey item examining gains in “Becoming a scientist” (including items such as: “Ability to work independently”, “Developing patience with the slow pace of research”, “Understanding what everyday research work is like” and “Taking greater care in conducting procedures in the lab or field”), again 100% of students reported gains. More than 70% of students believed they had made ‘good’ or ‘great’ gains in every area related to “Becoming a scientist”.

When asked about gains in “Skills”, > 90% of all responses indicated gains in all items, including “making oral presentations”, “conducting observations in the lab or field”, “managing my time” and “keeping a detailed lab book”.

When asked to report on “Personal gains related to research work” (comprised of items including: “Confidence in my ability to do research”, “Comfort in discussing scientific concepts with my supervisor”, “Comfort in working collaboratively with others”), 100% of students reported making gains as a result of their research experiences.

Although the survey response rate was low (13%), the positive responses by students to their research experiences are in line with previous studies of the benefits of UR experiences (e.g., Seymour et al. 2004; Hunter et al. 2007) . Similar levels of student gains were documented using this survey instrument in another Australian context (Myatt 2009). Given that essentially 100% of students reported gains, there is little room for additional interpretation, however it is important to acknowledge the low response rate and to be cautious when drawing conclusions.

Comparison of staff and student perceptions

This study offered the opportunity to compare the anticipated student benefits from UR as reported by academics with the benefits reported by the students themselves. Whilst the gains are discussed separately above, the use of consistent categories makes it possible to examine the categories of student gains and consider any alignments. The students reported consistently high learning gains across the four categories: personal/professional gains, “thinking and working like a scientist”, skills, becoming a scientist. This level of consistency is not present in the academics’ predictions.

The first point to note relates to the category “Becoming a scientist”. In this study students report strong gains in this category, but the data from academic interviews does not reveal a matching level of awareness of this area of student-gain. Laursen et al. (2010) found that academic advisors are more likely to report gains in this category than are students. They suggested advisors are more likely to notice the new understandings of science expressed by students. Why don't our academics clearly state that "Becoming a scientist" is a student gain they expect from research experiences? One explanation for this inconsistency (or gap) may lie in the types of UR experiences in our study – where the experiences are predominantly within the curriculum. Laursen et al. (2010) explain that close ties exist between the category "Thinking and working like a scientist" and the category "Becoming a scientist". These categories have some commonalities: the former encapsulates the development of students to become more scientific in their approach to problem solving, while the latter moves on to issues of identity (as a scientist). It may be possible that, in the context of this study, that academics designing UR experiences within the curriculum focus more on the development of sciences skills and ways of working, and focus less on student identity development of "becoming a scientist". Alternatively, it may be that academics do not readily consider these as discrete categories.

A second point to note lies in the category "Personal/Professional". Once again, almost 100% of students reported making gains in the area of "confidence", but only five of the 61 comments by academics reflected their awareness of student gains in this category. It is possible that this silence by academics may signal a lack of awareness of the broader benefits of UR experiences. A "limited perspective" was also observed among research supervisors in a study at a similarly research-intensive, Australian university (Wilson, Howitt, Wilson and Roberts 2010). Their study of academics who supervised undergraduate student research projects found many academics did not appreciate the broader benefits of student research experiences. Wilson et al. (2010) suggested that a possible explanation might lie in the 'research only' role of some academics in that study. However this explanation would not apply here. The seminal work of Hunter et al. (2007) reported that "faculty and students addressed the same types of gains, but interpreted certain gains differently" (2007; p.44) and suggested that this was partly a consequence of staff framing their observations based on "long professional experience" (2007; p.44): those academics reported seeing broader student gains (expressed as "becoming a scientist"). In contrast, our study suggests a lesser awareness of this professionalisation but a greater awareness of skills development - leading to the emphasis on gains in "Thinking and working like a scientist" and in "Skills" themselves. Further investigation is needed to understand and fully interpret this silence by academics in this study.

One suggestion to further this work would be enabling academics to respond to the same survey as the students but following after their interviews. This additional prompted data would add an additional dimension to their 'unprompted' interview responses and enhance the comparison with student responses.

Conclusions and implications

This paper has sought to compare the views of academics on the benefits of research and inquiry experiences with those of students. Our findings suggest that some academics may have a limited view of the benefits of UR. This has several important implications for university policy makers and leaders in teaching and learning.

First, the results suggest that academics may under-estimate the breadth of benefits that students gain from research experiences. This should ring some alarm bells in the minds of those advocating research-based learning. As the higher education sector moves to develop students as 21st century problem-solvers, it is essential that the broader student benefits from UR experiences – not disciplinary skills and knowledge alone – are widely appreciated and valued. Increased emphasis on student research experiences will support students to acquire, and demonstrate, broader graduate outcomes. Furthermore, students can begin to gain these broad skills/qualities early in their undergraduate careers, opening up the discussion for the introduction of research experiences from the first year of university study. Those making policy decisions need to be aware of the broad range of skills developed through research experiences.

Second, at school or department level, these findings provide evidence which may prove useful where research and inquiry experiences are under threat. Teaching budgets often face reductions, and UR is frequently the first to be cut. These findings provide new motivations to retain UR experiences within the curriculum, and move away from a perception of academics who may previously have focussed on only the disciplinary gains from student research. Again, this requires a high level of awareness of the breadth of student gains from UR experiences.

Thirdly, these findings are directly relevant to the national disciplinary debate about threshold learning outcomes in science. Jones, Yates and Kelder (2011) articulated a nationally agreed set of science threshold learning outcomes (STLOs) for graduates of bachelor-level science degrees in Australia which was endorsed by the Australian Council of Deans of Science. Undergraduate research is encapsulated within four of the five TLOs, including: *Understanding science; Inquiry and problem-solving; Communication;* and *Personal and professional responsibility*. The Science Standards Statement (Jones et al. 2011) acknowledges that not all science graduates will work as professional scientists, but stresses the need to ensure that all science graduates can function as scientifically literate members of society. This study reconfirms the gains students make through UR experiences, and therefore emphasises the important role of UR in ensuring that graduates meet the national STLOs.

Finally, this research provides an important addition to existing literature promoting student benefits from UR. Even acknowledging the small sample size of this study, academic and student views on the benefits of UR appear to differ. Whereas academics are focussed on skill development, students are gaining a better understanding of what it is to be a scientist and the process of science, and are forming identities and gaining confidence. While our aim was to put undergraduate research-based learning "under the microscope" to investigate student benefits, we uncovered an unexpected contrast between students and academics perceptions of benefits. This contrast requires additional examination.

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