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Undergraduate Research or Research-Based Courses: Which Is Most Beneficial for Science Students?

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Abstract Over the last 25 years, both research literature and practice-oriented reports have claimed the need for improving the quality of undergraduate science education through linking research and teaching. Two manners of doing this are reported: undergraduate research and research-based courses. Although there are studies reporting benefits of participating in these experiences, few synthesize their findings. In this article, we present a literature review aimed at synthesizing and comparing results of the impact of participating in these research experiences to establish which approach is most beneficial for students to develop as scientists. Twenty studies on student participation in undergraduate research and research-based courses were reviewed. Results show that both types of experiences have positive effects on students. These results have implications for both practice and research. Regarding practice, we propose ideas for designing and implementing experiences that combine both types of experiences. Concerning research, we identify some methodological limitations that should be addressed in further studies.

Keywords Undergraduate research · Research-based courses · Science education · Teaching-research nexus · Higher education

Introduction

Previous research on the teaching-research nexus has claimed that students obtain significant benefits from participating in learning experiences which include research, for example, development of high-level competencies (such as problem formulation, data analysis, writing, collaboration, and critical thinking), a better understanding of the disciplines they are learning, and clarification of career pathways (e.g., Healey and Jenkins 2009; Hunter et al. 2007).

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Concurrently, practice-oriented reports have established the need for improving undergraduate education through linking teaching and research. At a general level, *The Boyer Report* (Boyer Commission 1999) made recommendations for improving undergraduate education in research universities. Amongst them, the report emphasized that inquiry-based learning should be the norm and advocated for the incorporation of inquiry learning activities from the very first year, as well as proposing to eliminate obstacles to interdisciplinary learning. In the area of science, in particular, there have also been reports promoting linking teaching and research (see, for example, American Association for the Advancement of Science 2009; National Research Council 2003). These reports align with Boyer's and emphasize the need for introducing students to scientific research early in their studies, using inquiry learning methods, and therefore giving the tools for facing change in disciplinary knowledge, promoting interdisciplinarity and providing authentic research experiences for undergraduates.

Two forms through which linking teaching and research can be realized are reported in the literature: undergraduate research and research-based courses. Undergraduate research is defined by the *Council of Undergraduate Research* (2016) as "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline," although some researchers define it more broadly (e.g., Beckman and Hensel 2009). It tends to occur in summer programs and in collaboration with a tutor. This type of experiences allows students to see how research happens *from the inside* and to know how the scientific community works (Wei and Woodin 2011). On the other hand, research-based courses involve more students as they just need to enroll in a course to participate in research experiences. This implies that the whole course participates in answering a research question or solving a research problem whose result is unknown and is of interest for the scientific community (Auchincloss et al. 2014). Auchincloss et al. (2014) established differences between undergraduate research and research-based courses: (1) research-based courses involve more students than undergraduate research programs; (2) research-based courses are open to all students enrolled in a course, while students need to apply to undergraduate research programs; (3) undergraduate research is more demanding for academics, who need to spend similar amounts of time with very few students; (4) research-based courses happen inside the classroom, in students' labs, and during the scheduled classes, while undergraduate research happens outside of the classroom, in a research lab, and mainly during summer; and (5) research-based courses tend to develop, following Boyer's recommendations, mainly during the first years in an undergraduate program, while undergraduate research may occur at any time during the degree but mainly during the last years. Both types of experiences have their roots in the US higher education, and with variations, they have been widely adopted in countries such as Australia, Canada, New Zealand, and the UK (Healey and Jenkins 2009).

Despite the benefits this kind of experiences have on students, as reported in the literature, few articles synthesize these findings. In the case of undergraduate research, there is an exhaustive review by Sadler et al. (2010) related to the effects of research apprenticeships on secondary students, undergraduates students, and teachers. Regarding research-based courses, there is a report by Auchincloss et al. (2014) in which the focus is to define what they are and to summarize research on assessment and evaluation of this type of experiences, however is not an exhaustive review of the literature. Besides, although there are works that have compared the effects of both types of experiences (e.g., Denofrio et al. 2007; Lopatto et al. 2008), there is no systematization of research results. Based on the significant effects that engagement in undergraduate research or research-based courses has on science students, it is important to conduct a literature review that allows synthesizing and comparing the results of

related studies. It may allow establishing which type of experience is most beneficial, i.e., the one that offers better opportunities, for their development as scientists. Therefore, the question framing our review is: Which type of experiences is most beneficial for science students to develop as scientists? In this way, this review will provide relevant evidence for university teachers, curriculum designers, and academic managers to decide what type of learning experiences they may organize for students.

Methods

Steps in conducting this review were the following:

1. Several searches were conducted in *Web of Knowledge* and *Scopus*, using different combinations of the following keywords: *research*, *science*, *undergraduate*, *apprenticeship*, *authentic*, and *experience*. The time of publication was limited to 2004–2014. A set of 119 articles was found.
2. Then, each article abstract was reviewed to see whether it covered the topic of the review. Only empirical articles were included. The search was also limited to research on scientific majors leading to completion of an undergraduate degree: studies on professional degrees were excluded.
3. In the next step, the reference lists of selected articles were reviewed. This allowed relevant articles to be found that did not appear in the searches in the bibliographic databases.
4. Twenty articles met our criteria for this review (indicated by * in the References section). Nineteen of them correspond to research carried out in the USA and one corresponds to Australia. From the 20 articles, five analyzed both types of experiences, and three of these papers made another type of comparison; hence, their results were employed in the analysis twice: (1) when comparing research-based courses with traditional courses or when comparing courses with different amount of hours devoted to the research project, results were included in the group of papers focused on research-based courses; and (2) when comparing research-based courses with undergraduate research programs, results were included in the group of papers focused on comparing both experiences.
5. Analysis of the articles included in this review permits the assertion that most of the results can be classified using the major categories developed by Hunter et al. (2007): (1) thinking and working like a scientist, (2) becoming a scientist, (3) personal-professional, (4) clarification, confirmation, and refinement of career/education paths, (5) enhanced career/graduate school preparation, and (6) skills. The exception is a result related to changes in students' interests after participating in research-based courses. Therefore, the category *clarification*, *confirmation*, *and refinement of career/education paths* was changed to *professional-educational trajectories* to include results not only related to keeping students' interests but also with changes in them. Table 1 presents a description of the categories used in this review.
6. In the tables made for each category, results of the positive effects of student participation in research-based courses or undergraduate research programs are reported. When comparing different experiences, (1) research-based courses with traditional courses, (2) courses with different amount of hours devoted to the research project, or (3) research-based courses with undergraduate research programs, only results in which experiences

Table 1 Description of the categories adapted from Hunter et al. (2007) and used to organize the main results of the selected articles

Category	Description of category
Thinking and working like a scientist	Application of knowledge and skills: use of cognitive skills, such as critical thinking and problem solving, understanding of the nature of scientific knowledge. Knowledge and understanding of science and research work: connections within and between the areas of science, the connection between research and courses
Becoming a scientist	Attitudes and behaviors necessary to become a scientist. Understanding of professional practice and the nature of research work
Personal-professional	Increase in confidence to do research, contribute to science, and "feeling like a scientist." Establishing relationships with academics and other students participating in research experiences
Professional-educational trajectories	Change, clarification, or confirmation of interest and/or professional-educational plans
Enhanced career/graduate school preparation	Preparation for working world and graduate school
Skills	Improvement in skills such as oral communication, scientific writing, data analysis, interpretation of results, understanding of primary literature, laboratory, independent work, and collaborative work

compared were different were reported. If a study did not discuss a category or subcategory and therefore did not report results for it, this was reported in the table as n.d. (not discussed).

This literature review is not intended to be a systematic review since it examines the results of selected articles according to the criteria in steps 1 and 2.

Results

Findings from articles included in this review were classified into six categories: (1) thinking and working like a scientist, (2) becoming a scientist, (3) personal-professional, (4) professional-educational trajectories, (5) enhanced career/graduate school preparation, and (6) skills. Results for each category are presented below.

Thinking and Working Like a Scientist

Research on students participating in research-based courses reported that they perceived positive effects on their understanding of the research process (Balster et al. 2010; Burnette and Wessler 2013; Harrison et al. 2011; Jordan et al. 2014; Lopatto et al. 2008; Shaffer et al. 2014), understanding of science (Balster et al. 2010; Burnette and Wessler 2013; Jordan et al. 2014; Lopatto et al. 2008; Russell and Weaver 2011; Shaffer et al. 2014), understanding of how knowledge is constructed (Jordan et al. 2014; Lopatto et al. 2008; Shaffer et al. 2014), understanding of how scientists think (Burnette and Wessler 2013; Jordan et al. 2014; Lopatto et al. 2008; Shaffer et al. 2014), and understanding of potential uses of knowledge and skills learned (Shaffer et al. 2014). These results appeared both in studies where data was gathered only at the end of the course and where data was collected up to 7 years later only.

Research on students involved in undergraduate research also reported they perceived getting a better understanding of the research process (Cartrette and Melroe-Lehrman 2012; Lopatto 2004, 2007), understanding of science (Lopatto 2004, 2007), understanding of how knowledge is constructed (Cartrette and Melroe-Lehrman 2012; Lopatto 2004, 2007), understanding of how scientists think (Lopatto 2004, 2007), and understanding of potential uses of knowledge and skills learned (Hunter et al. 2007; Seymour et al. 2004). These results appeared in studies where data was gathered only at the end of the course and those where data was collected at the end of the course and 4 or 9 months later.

For studies comparing the effects of student participation in research-based courses and undergraduate research programs, positive results in favor of the former were reported. Students who participated in research-based courses showed deeper understanding of science (Denofrio et al. 2007; Jordan et al. 2014; Shaffer et al. 2014), deeper understanding of how knowledge is constructed (Denofrio et al. 2007; Jordan et al. 2014; Lopatto et al. 2008; Shaffer et al. 2014), deeper understanding of how scientists think (Denofrio et al. 2007; Jordan et al. 2014; Shaffer et al. 2014), and better understanding of potential uses of knowledge and skills learned (Thiry et al. 2011). In relation to understanding of the research process, Denofrio et al. (2007) and Jordan et al. (2014) reported that students who participated in research-based courses expressed higher levels of achievement than those who did in undergraduate research programs, while Thiry et al. (2011)[1] reported the reverse pattern.

Therefore, these results suggested that students' participation in research-based courses or undergraduate research programs had both positive effects on all the aspects related to the *thinking and working like a scientist* category. On the other hand, considering studies comparing these experiences, students who participated in research-based courses tended to perceive greater effects, except for the subcategory *understanding of research process*, where positive results for both were reported. Table 2 presents a summary of the articles' results for each subcategory.

Becoming a Scientist

Research on the impact of student participation in research-based courses reported that they perceived a positive impact on understanding the nature of research work (Balster et al. 2010), developing an identity as scientists (Harrison et al. 2011; Shaffer et al. 2014; Szteinberg and Weaver 2013), understanding of professional practice (Balster et al. 2010), and development of attitudes and behaviors required for practicing science (Balster et al. 2010; Jordan et al. 2014; Lopatto et al. 2008; Shaffer et al. 2014; Szteinberg and Weaver 2013). These results were reported in studies where data was gathered only at the end of the course, those where data was gathered at the end of the course and 2 to 3 years later and where data was collected up to 7 years later only.

Research on the impact of student participation in undergraduate research programs also reported that they perceived a positive impact on understanding the nature of research work (Cartrette and Melroe-Lehrman 2012), developing an identity as scientists (Hunter et al. 2007), understanding of professional practice (Russell et al. 2007), and development of attitudes and

[1] The authors grouped the different activities, curricular and extracurricular, in which students had participated, in three categories: research experience (e.g., summer research programs.), work experience (e.g., clinic programs, internship), and campus experiences (e.g., research-based courses). Regarding this review, the "research experiences" category refers to undergraduate research programs, while "campus experience" category refers to research-based courses.

Table 2 Articles reporting benefits related to *thinking and working like a scientist* category

	Understanding of research process	Understanding of science	Understanding of how knowledge is constructed	Understanding of how scientists think	Application of knowledge and skills
(a) Studies on research-based courses					
Balster et al. (2010)	✓[a]	✓[b]**	n.d.	n.d.	n.d.
Burnette and Wessler (2013)	✓[c]	✓[c]	n.d.	✓[c]	n.d.
Harrison et al. (2011)	✓[a]	n.d.	n.d.	n.d.	n.d.
Jordan et al. (2014)	✓[d]	✓[d]	✓[d]	✓[d]	n.d.
Lopatto et al. (2008)	✓[d]	✓[d]	✓[d]	✓[d]	n.d.
Russell and Weaver (2011)	n.d.	✓[e]	n.d.	n.d.	n.d.
Shaffer et al. (2014)	✓[f]	✓[f]	✓[f]	✓[f]	✓ (RS)[g]
(b) Studies on undergraduate research programs					
Cartrette and Melroe-Lehrman (2012)	✓[h]	n.d.	✓[h]	n.d.	n.d.
Hunter et al. (2007)[i]					✓ (CT, PS)[j]
Lopatto (2004)	✓[j]	✓[j]	✓[j]	✓[j]	n.d.
Lopatto (2007)	✓[k]	✓[k]	✓[k]	✓[k]	n.d.
Seymour et al. (2004)[i]					✓ (CT, PS)[j]
(c) Studies comparing research-based courses and undergraduate research programs					
Denofrio et al. (2007)	✓[l]	✓[l]	✓[l]	✓[l]	n.d.
Jordan et al. (2014)	✓[l]	✓[l]	✓[l]	✓[l]	n.d.
Lopatto et al. (2008)			✓[l]		n.d.
Shaffer et al. (2014)		✓[l]	✓[l]	✓[l]	n.d.
Thiry et al. (2011)	✓[m]	n.d.	n.d.	n.d.	✓ (CT, PS)[l]

Application or use of specific skills is in parentheses

RS research skills after graduation, *CT* critical thinking skills, *PS* problem solving skills, *n.d.* not discussed (n.d. denotes that the study did not discuss a category or subcategory and therefore did not report results for it)

[a] Gain reported by students at the end of the course (content analysis)

[b] Positive gain (difference between post and pretest)

[c] Gain reported by students at the end of the course

[d] Positive difference in favor of research-based courses when compared with traditional courses

[e] Research-based course students presented more sophisticated conceptions when compared with traditional course students (phenomenographic analysis)

[f] Positive difference in favor of courses that devoted more hours to the research project when compared with courses that devoted less hours

[g] Positive difference in favor of courses that devoted more hours to the research project when compared with courses that devoted less hours (alumni responses)

[h] Gain reported by students at the end of the programs and 4 months later (phenomenological analysis)

[i] In this table, only positive comments ≥20% are reported

[j] Gain reported by students at the end of the programs

[k] Gain reported by students at the end of the programs and 9 months later

[l] Positive difference in favor of research-based courses

[m] Positive difference in favor of undergraduate research programs

**$p < .01$

behaviors required for practicing science (Hunter et al. 2007; Lopatto 2004, 2007). These results were reported both in studies where data was gathered at the end of the course and those where data was collected at the end of the course and 4 or 9 months later or 2 years later.

In the case of research comparing the effects of student participation in research-based courses and undergraduate research programs, Thiry et al. (2011) reported that students who participated in undergraduate research expressed higher levels of achievement in both developing an identity as scientists and understanding of professional practice. Regarding the development of different attitudes and behaviors required for practicing science, Denofrio et al. (2007) and Jordan et al. (2014) reported higher levels of achievement in students who participated in research-based courses in all attitudes and behaviors evaluated (independence, tolerance, ethics, readiness), while Shaffer et al. (2014) reported higher levels of achievement only in ethics. On the other hand, Lopatto et al. (2008) and Thiry et al. (2011) reported higher levels of achievement in students participating in undergraduate research programs, in ethics and independence, respectively.

In summary, studies that inquired into the participation of students in research-based courses as well as those who did undergraduate research programs showed a positive effect on their perception of development as scientists in all subcategories (*understanding of the nature of research work*, *developing an identity as a scientist*, *understanding of professional practice* and *attitude and behavior for practicing science*). However, one of the studies that compared the effects of both types of experiences showed that undergraduate research programs had an impact on the subcategories of *developing an identity as a scientist* and *understanding of professional practice*. For the subcategory *attitude and behavior for practicing science*, positive evidence was reported for both types of experiences. Table 3 presents a summary of the articles' results for each subcategory.

Personal-Professional

A positive effect on various confidence-related aspects was perceived by students participating in research-based courses (Balster et al. 2010; Canaria et al. 2012; Rowland et al. 2012; Shaffer et al. 2014; Szteinberg and Weaver 2013) and in undergraduate research programs (Hunter et al. 2007; Lopatto 2004, 2007; Russell et al. 2007; Seymour et al. 2004) (see Table 4). These results were reported in studies where data was gathered only at the end of the course, those where data was gathered at the end of the course and 9 months or 2 to 3 years later and where data was collected up to 7 years later only.

In the case of research studies comparing the effects of student participation in research-based courses and undergraduate research programs, positive results were reported for both types of experiences. Denofrio et al. (2007) showed that students who participated in research-based courses expressed a higher level of confidence than those who did undergraduate research programs. Conversely, Thiry et al. (2011) reported that students participating in undergraduate research programs expressed higher levels of confidence. Furthermore, the results of Thiry et al. (2011) show that students who participated in undergraduate research programs perceived a positive effect on the development of relationships with professionals in their area.

To summarize, both studies investigating the participation of students in research-based courses and those studying undergraduate research programs showed a positive effect on their confidence level. When comparing the effects of both types of

Table 3 Articles reporting benefits related to *becoming a scientist* category

	Understanding of the nature of research work	Developing an identity as a scientist	Understanding of professional practice	Attitude and behavior for practicing science
(a) Studies on research-based courses				
Balster et al. (2010)	✓[a]**	n.d.	✓[a]**	✓ (I, T)[a]**
Harrison et al. (2011)	n.d.	✓[b]	n.d.	n.d.
Jordan et al. (2014)	n.d.	n.d.	n.d.	✓ (E, I, RA, T)[c]
Lopatto et al. (2008)	n.d.	n.d.	n.d.	✓ (I, RA, T)[c]
Shaffer et al. (2014)	n.d.	✓[d]	n.d.	✓ (E, I, RA, T)[e]
Szteinberg and Weaver (2013)	n.d.	✓[f]	n.d.	✓ (C)[g]
(b) Studies on undergraduate research programs				
Cartrette and Melroe-Lehrman (2012)	✓[h]	n.d.	n.d.	n.d.
Hunter et al. (2007)[i]		✓[j]		✓ (I, RE)[j]
Lopatto (2004)	n.d.	n.d.	n.d.	✓ (E, I, RA, T)[j]
Lopatto (2007)	n.d.	n.d.	n.d.	✓ (E, I, RA, T)[k]
Russell et al. (2007)	n.d.	n.d.	✓[l]	n.d.
(c) Studies comparing research-based courses and undergraduate research programs				
Denofrio et al. (2007)	n.d.	n.d.	n.d.	✓ (E, I, RA, T)[m]
Jordan et al. (2014)	n.d.	n.d.	n.d.	✓ (E, I, RA, T)[m]
Lopatto et al. (2008)	n.d.	n.d.	n.d.	✓ (E)[n]
Shaffer et al. (2014)	n.d.	n.d.	n.d.	✓ (E)[m]
Thiry et al. (2011)	n.d.	✓[m]	✓[m]	✓ (I)[n]

Specific attitudes and behaviors developed are in parentheses

I independence, *T* tolerance, *C* creativity, *RE* responsibility, *E* ethics, *RA* readiness, *n.d.* not discussed (n.d. denotes that the study did not discuss a category or subcategory and therefore did not report results for it)

[a] Positive gain (difference between post and pretest)

[b] Gain reported by students at the end of the course (content analysis)

[c] Positive difference in favor of research-based courses when compared with traditional courses

[d] Gain reported by alumni (frequency analysis)

[e] Positive difference in favor of courses that devoted more hours to research project when compared with courses that devoted less hours

[f] Gain reported by research-based course students after 2–3 years of the end of the course (content analysis)

[g] Positive difference in favor of research-based course when compared with traditional course after 2–3 years of the end of the course

[h] Gain reported by students at the end of the programs and 4 months later (phenomenological analysis)

[i] In this table, only positive comments ≥20% are reported

[j] Gain reported by students at the end of the programs

[k] Gain reported by students at the end of the programs and 9 months later

[l] Gain reported by more than 80% of students after 2 years of the end of the programs

[m] Positive difference in favor of research-based courses

[n] Positive difference in favor of undergraduate research programs

**$p < .01$

experiences, positive results were found for both. Table 4 presents a summary of the articles' results for each subcategory.

Professional-Educational Trajectories

Research on the impact of student participation in research-based courses reported that they perceived positive effects on their interest in science (Harrison et al. 2011; Shaffer et al. 2014.),

Table 4 Articles reporting benefits related to *personal-professional* category

	Confidence
(a) Studies on research-based courses	
Balster et al. (2010)	To discuss scientific issues, to explain their research, and to make a contribution to research team[a]**
Canaria et al. (2012)	In their research skills, such as performing research, designing experiments, interpreting results, and drawing conclusions[a]
Rowland et al. (2012)	In three laboratory research skills (running an enzyme assay, planning my own experiments, doing enzyme kinetics calculations) out of 25 skills evaluated[b]***
Shaffer et al. (2014)	To discuss scientific issues[c]
Szteinberg and Weaver (2013)	To do research[d]
(b) Studies on undergraduate research programs	
Hunter et al. (2007)[e]	To do research and contribute to science[f]
Lopatto (2004)	Self-confidence[f]
Lopatto (2007)	Self-confidence[g]
Russell et al. (2007)	In their research skills[h]
Seymour et al. (2004)[e]	To do research and contribute to science[f]
(c) Studies comparing research-based courses and undergraduate research programs	
Denofrio et al. (2007)	Self-confidence[i]
Thiry et al. (2011)	To do research and contribute to science[j]

For each research, the area in which there was an increase in confidence is specified

[a] Positive gain (difference between post and pretest)

[b] Positive difference in favor of research-based course when compared with a traditional course

[c] Positive difference in favor of courses that devoted more hours to research project when compared with courses that devoted less hours (alumni responses)

[d] Positive difference in favor of research-based course when compared with traditional course after 2–3 years of the end of the course

[e] In this table, only positive comments ≥20% are reported

[f] Gain reported by students at the end of the programs

[g] Gain reported by students at the end of the programs and 9 months later

[h] Gain reported by more than 80% of students after 2 years of the end of the programs

[i] Positive difference in favor of research-based courses

[j] Positive difference in favor of undergraduate research programs

$^{**}p < .01$; $^{***}p < .001$

career options (Balster et al. 2010; Harrison et al. 2011; Jordan et al. 2014; Lopatto et al. 2008; Shaffer et al. 2014), and career trajectories after they had taken such courses (Canaria et al. 2012; Shaffer et al. 2014). These results were reported both in studies where data was gathered at the end of the course and where data was collected up to 7 years later only.

On the other hand, research on the impact of student participation in undergraduate research reported that they perceived a positive effect on their career options (Hunter et al. 2007; Lopatto 2004, 2007; Russell et al. 2007; Seymour et al. 2004). These results were reported both in studies where data was gathered only at the end of the course and those where data was gathered at the end of the course and 9 months or 2 years later.

In the case of research comparing the effects of student participation in research-based courses and undergraduate research programs, they mostly reported positive

results in favor of both types of experience, in relation to their career options. However, Denofrio et al. (2007) and Jordan et al. (2014) reported that students who participated in research-based courses expressed greater clarity regarding their career options than those who did undergraduate research programs. Furthermore, Lopatto et al. (2008) and Thiry et al. (2011) reported the reverse pattern.

In summary, studies on the effects of research-based courses and those focused on undergraduate research programs showed positive results. In the case of research-based courses, positive effects were found on all subcategories (*interest in science*, *career options*, and *academic pathways*) while in the case of undergraduate research positive effects were reported on the subcategory of *career options*. When comparing the effects of both types of experiences in students' career options, positive results were reported for both research experiences. Table 5 presents a summary of the articles' results for each subcategory.

Enhanced Career/Graduate School Preparation

Research on students who participated in research-based courses reported that they perceived positive effects on their education (Burnette and Wessler 2013; Canaria et al. 2012), preparation for graduate school (Shaffer et al. 2014), and preparation for real-world work (Shaffer et al. 2014; Szteinberg and Weaver 2013). These results were reported in studies where data was gathered at the end of the course, those where data was gathered at the end of the course and 2 to 3 years later and where data was collected up to 7 years later only.

Research on students participating in undergraduate research programs also reported that they perceived positive effects on their current education (Lopatto 2007), participation in new experiences (Hunter et al. 2007; Lopatto 2007), preparation for real-world work (Hunter et al. 2007; Seymour et al. 2004), and development of professional networks (Hunter et al. 2007; Seymour et al. 2004). These results appeared both in studies where data was gathered at the end of the course and those where data was gathered at the end of the course and 9 months later.

Thiry et al. (2011) compared the effects of student participation in research-based courses and undergraduate research programs. Their results showed that students who participated in undergraduate research programs perceived a greater effect both in preparation for graduate school and real-world work.

In conclusion, both the results of studies on research-based courses and those which focused on undergraduate research programs showed positive effects in preparing students for the academic and/or professional world. The study which compared both types of experiences (Thiry et al. 2011) showed that students who participated in undergraduate research programs perceived greater effects. Table 6 presents a summary of the articles' results for each subcategory.

Skills

Research on the impact of student participation in research-based courses reported that, at the end of the course, they expressed higher levels of achievement regarding their oral communication skills (Canaria et al. 2012; Jordan et al. 2014; Lopatto et al. 2008; Shaffer et al. 2014), writing skills (Jordan et al. 2014; Lopatto et al. 2008; Shaffer et al. 2014), research skills (Balster et al. 2010; Burnette and Wessler 2013; Jordan et al. 2014; Lopatto et al. 2008; Shaffer et al. 2014), laboratory

Table 5 Articles reporting benefits related to *professional-educational trajectories* category

	Interest in science	Career options	Career trajectories
(a) Studies on research-based courses			
Balster et al. (2010)	n.d.	✓ (CL)[a]**	n.d.
Canaria et al. (2012)	n.d.	n.d.	✓[b]
Harrison et al. (2011)	✓[a]*	✓ (CH)[c]	n.d.
Jordan et al. (2014)	n.d.	✓ (CL)[d]	n.d.
Lopatto et al. (2008)	n.d.	✓ (CL)[d]	n.d.
Shaffer et al. (2014)	✓[e]	✓ (CL)[e]	✓[f]
(b) Studies on undergraduate research programs			
Hunter et al. (2007)[g]		✓ (CL)[h]	n.d.
Lopatto (2004)	n.d.	✓ (CL)[h]	n.d.
Lopatto (2007)	n.d.	✓ (CL)[i]	n.d.
Russell et al. (2007)	n.d.	✓ (CH, CL)[j]	n.d.
Seymour et al. (2004)[g]		✓ (CL)[h]	n.d.
(c) Studies comparing research-based courses and undergraduate research programs			
Denofrio et al. (2007)	n.d.	✓ (CL)[k]	n.d.
Jordan et al. (2014)	n.d.	✓ (CL)[k]	n.d.
Lopatto et al. (2008)	n.d.	✓ (CL)[l]	n.d.
Thiry et al. (2011)	n.d.	✓ (CL)[l]	n.d.

Specific effect on career options is in parentheses

CL clarifying, *CH* changing, *n.d.* not discussed (n.d. denotes that the study did not discuss a category or subcategory and therefore did not report results for it)

[a] Positive gain (difference between post and pretest)

[b] It reported that, of the total of participants, 44% plan to attend graduate school, 50% plan to attend a professional school, and 6% plan to pursue an M.D.-Ph.D

[c] Gain reported by students at the end of the course (content analysis)

[d] Positive difference in favor of research-based courses when compared with traditional courses

[e] Positive difference in favor of courses that devoted more hours to research project when compared with courses that devoted less hours (alumni responses)

[f] Three largest areas of current occupation reported by the alumni were being a postsecondary student in science (30%), medical school student (22%), and employment in science (19%)

[g] In this table, only positive comments ≥20% are reported

[h] Gain reported by students at the end of the programs

[i] Gain reported by students at the end of the programs and 9 months later

[j] Gain reported by students after 2 years of the end of the programs

[k] Positive difference in favor of research-based courses

[l] Positive difference in favor of undergraduate research programs

*$p < .05$; **$p < .01$

skills (Balster et al. 2010; Burnette and Wessler 2013; Canaria et al. 2012; Jordan et al. 2014; Lopatto et al. 2008), and their understanding of primary literature (Balster et al. 2010; Canaria et al. 2012; Jordan et al. 2014; Lopatto et al. 2008; Shaffer et al. 2014).

Research studies on the impact of student participation in undergraduate research reported that they perceived a positive impact on their oral communication skills (Hunter et al. 2007; Lopatto 2004, 2007; Seymour et al. 2004), writing skills (Lopatto 2004, 2007), research skills (Feldman et al. 2013; Frantz et al. 2006; Lopatto 2004, 2007), laboratory skills (Feldman et al. 2013; Hunter et al. 2007;

Table 6 Articles reporting benefits related to *enhanced career/graduate school preparation* category

	Current education	Preparation for graduate school	Participation in new career-related experiences	Preparation for real-world work	Development of professional networks
(a) Studies on research-based courses					
Burnette and Wessler (2013)	✓[a]	n.d.	n.d.	n.d.	n.d.
Canaria et al. (2012)	✓[b]	n.d.	n.d.	n.d.	n.d.
Shaffer et al. (2014)	n.d.	✓[c]	n.d.	✓[d]	n.d.
Szteinberg and Weaver (2013)	n.d.	n.d.	n.d.	✓[e]	n.d.
(b) Studies on undergraduate research programs					
Hunter et al. (2007)[f]	n.d.		✓[g]	✓[g]	✓[g]
Lopatto (2007)	✓[h]	n.d.	✓[h]	n.d.	n.d.
Seymour et al. (2004)[f]	n.d.			✓[g]	✓[g]
(c) Studies comparing research-based courses and undergraduate research programs					
Thiry et al. (2011)	n.d.	✓[i]	n.d.	✓[i]	n.d.

n.d. not discussed (n.d. denotes that the study did not discuss a category or subcategory and therefore did not report results for it)

[a] Gain reported by students at the end of the course

[b] Positive gain (difference between post and pretest)

[c] Positive difference in favor of courses that devoted more hours to research project when compared with courses that devoted less hours (alumni responses)

[d] Gain reported by alumni (frequency analysis)

[e] Positive difference in favor of research-based course when compared with traditional course after 2–3 years of the end of the course

[f] In this table, only positive comments ≥20% are reported

[g] Gain reported by students at the end of the programs

[h] Gain reported by students at the end of the programs and 9 months later

[i] Positive difference in favor of undergraduate research programs

Lopatto 2004, 2007; Seymour et al. 2004), and their understanding of primary literature (Lopatto 2004, 2007). These results were found both in studies where data was gathered only at the end of the course and those where data was gathered at the end of the course and 9 months later.

In the case of research comparing the effects of student participation in research-based courses and undergraduate research programs, results revealed that those who participated in research-based courses expressed higher levels of achievement than those who participated in undergraduate research regarding their oral communication skills (Denofrio et al. 2007; Shaffer et al. 2014; Thiry et al. 2011), writing skills (Denofrio et al. 2007; Jordan et al. 2014; Lopatto et al. 2008; Shaffer et al. 2014; Thiry et al. 2011), research skills (Denofrio et al. 2007; Jordan et al. 2014; Lopatto et al. 2008; Shaffer et al. 2014), and understanding primary

literature (Denofrio et al. 2007). Regarding the effect on laboratory skills, evidence was found in favor of either type of experience. Jordan et al. (2014) reported that students who participated in research-based courses expressed higher levels of achievement than those who participated in undergraduate research programs, whereas Lopatto et al. (2008), Shaffer et al. (2014), and Thiry et al. (2011) reported the reverse pattern.

To sum up, results of studies on research-based courses as well as those focusing on undergraduate research showed positive effects on the development of various research-related skills. On the other hand, when comparing the effects of both types of experiences, students who participated in research-based courses reported higher levels of achievement than those who participated in undergraduate research programs, except for laboratory skills. In this case, positive results were reported for both types of experiences. Table 7 presents a summary of the articles' results for each subcategory.

Discussion

The objective of this article was to synthesize the results of studies on the effects that different research experiences (research-based courses and undergraduate research programs) may have in undergraduate science students. We wanted to compare them and to establish which type of experience is most beneficial, i.e., offered better opportunities, for their development as scientists. The analysis of the results revealed, with some nuances, that both types of experiences have positive effects on students.

Analysis of the results reported by studies on research-based courses and undergraduate research experiences confirmed that both produced positive effects on students. At the same time, considering studies that compare both types of experience, the evidence is inconclusive since positive effects are reported for each in at least some of the categories considered. This has important implications for practice. Coming back to the question framing our review, "Which type of experience is most beneficial for science students?", we now understand that both are beneficial. This implies that universities should assume the tasks of providing good quality research-based courses and, at the same time, undergraduate research experiences.

Several challenges arise from this. First, it is important to ensure that both research-based courses and undergraduate research programs meet minimum standards for qualifying as research. This means that students are engaged in research activities where they play an active role and not merely for example, following recipes for experiments in the case of research-based courses or doing routine work in the case of undergraduate research. For this to happen, proper design of these experiences is needed. Academic developers have an important role here in promoting quality experiences that will lead to students developing both the desired knowledge and research skills.

A second challenge is how to balance practical advantages of research-based courses with the more intense undergraduate research experiences. In fact, research-based courses may reach more students since they do not need to apply, as in undergraduate research programs. However, as the results of this literature review showed, undergraduate research generates similar and additional positive impacts since these experiences mainly happen in labs, require a closer collaboration with researchers, and provide opportunities for developing laboratory skills and professional networks with scientists. This balance also needs to consider evidence comparing both experiences since one is at an advantage over the other in some categories. For example, research-based courses seem to be better for the development of *thinking and*

Table 7 Articles reporting benefits related to *skills* category

	Communication	Research	Laboratory	Understanding primary literature
(a) Studies on research-based courses				
Balster et al. (2010)		✓ (DA)[a]**	✓[a]**	✓[a]**
Burnette and Wessler (2013)	n.d.	✓ (DC, DA, RI)[b]	✓[b]	n.d.
Canaria et al. (2012)	✓[a]	n.d.	✓[a]	✓[a]
Jordan et al. (2014)	✓[c]	✓ (DA, RI)[c]	✓[c]	✓[c]
Lopatto et al. (2008)	✓[c]	✓ (DA, RI)[c]		✓[c]
Shaffer et al. (2014)	✓[d]	✓ (DA, RI)[d]		✓[d]
(b) Studies on undergraduate research programs				
Feldman et al. (2013)	n.d.	✓ (DC, DR, RD)[e]	✓ (LFT)[e]	n.d.
Frantz et al. (2006)		✓ (RD)[a]*	n.d.	n.d.
Hunter et al. (2007)[f]	✓[g]	n.d.	✓[g]	n.d.
Lopatto (2004)	✓[g]	✓ (DA, RI)[g]	✓[g]	✓[g]
Lopatto (2007)	✓[h]	✓ (DA, RI)[h]	✓[h]	✓[h]
Seymour et al. (2004)[f]	✓[g]	n.d.	✓[g]	n.d.
(c) Studies comparing research-based courses and undergraduate research programs				
Denofrio et al. (2007)	✓[i]	✓[i]		✓[i]
Jordan et al. (2014)	✓[i]	✓ (DA, RI)[i]	✓[i]	
Lopatto et al. (2008)	✓[i]	✓ (DA)[i]	✓[j]	
Shaffer et al. (2014)	✓[i]	✓ (DA, RI)[i]	✓[j]*	
Thiry et al. (2011)	✓[i]	n.d.	✓[j]	n.d.

Specific research skills developed are in parentheses

DC data collection, *DA* data analysis, *RI* results interpretation, *DR* data report, *RD* research design (experimental or other), *LFT* laboratory and field techniques, *n.d.* not discussed (n.d. denotes that the study did not discuss a category or subcategory and therefore did not report results for it)

[a] Positive gain (difference between post and pretest)

[b] Gain reported by students at the end of the course

[c] Positive difference in favor of research-based courses when compared with traditional courses

[d] Positive difference in favor of courses that devoted more hours to the research project when compared with courses that devoted less hours

[e] Gain reported by students (phenomenological analysis)

[f] In this table, only positive comments ≥20% are reported

[g] Gain reported by students at the end of the programs

[h] Gain reported by students at the end of the programs and 9 months later

[i] Positive difference in favor of research-based courses

[j] Positive difference in favor of undergraduate research programs

*$p < .05$; **$p < .01$

working like a scientist and all subcategories of *skills* but *laboratory skills*. On the other hand, undergraduate research seems to be better, for example, for subcategories *developing an identity as a scientist* and *understanding of professional practice* both under category *personal-professional* or subcategories *preparation for graduate school* and *preparation for real-world work* both belonging to category *enhanced career/graduate school preparation*.

A third challenge is how to integrate both experiences. Literature shows that research-based courses tend to happen mainly during first years of the degree, while undergraduate research experiences occur during the last ones. There may be an alternative model where students start

with research-based courses and then take undergraduate research experiences. For more students to be part of undergraduate research experiences, there may be two options: bachelor's theses carried out under this form and/or optional courses enrolling small groups of students for them to participate in labs. Detailed curriculum planning for integrating research-like activities across the years of an undergraduate degree is required to ensure the progressive development of research skills. For example, Spronken-Smith et al. (2011) reported on a process of curricular change to provide a scaffolded approach to the development of critical thinking and research skills through inquiry activities and research-based courses throughout an ecology degree.

A final challenge is that all the implications mentioned above need to consider the characteristics of each institution. For example, massive institutions will have trouble accommodating students in credit-optional courses or guiding undergraduate theses, research-intensive universities may be able to provide more opportunities for research experiences, and so on. Adaptation to particular conditions needs to be considered to offer quality research-based courses and undergraduate research experiences to students.

Finally, it is important to acknowledge, for a proper understanding of the results presented, limitations emerging from the methods employed by the studies included in this paper. Four elements that must be considered and improved, concerning the methodology used, in further research: (1) data collection at different times during the development of experiences (e.g., pre-post) to establish whether they had an effect on students or not, with a benchmark (pretest); (2) the use of a comparison group (e.g., research-based courses versus traditional courses); (3) the inclusion of longitudinal studies for determining whether the effects of student participation in the various types of research experiences are maintained over time after they had finished; and (4) the use of statistical analysis, in the case of quantitative studies that made some comparison (e.g., pre-post), to determine whether achievement levels perceived by students are different from each other. Further research should consider these issues.

Conclusions

We set out to inquire which learning experience—research-based courses or undergraduate research—is most beneficial for science students' development as scientists. We found, from a detailed review of selected literature, that in general, both experiences are beneficial. From this finding, we propose that universities should make efforts to design research experiences where students play an active role and are not only following predetermined sets of activities, that a proper balance between research-based courses and undergraduate research should be sought, that both experiences should be explicitly integrated across the curriculum, and that particular features of each institution need to be considered in designing and developing research experiences. At the same time, we argue that further research in this area needs to consider some methodological issues. We think that attention needs to be given to collecting data in different moments of these experiences, that comparison groups are needed, that longitudinal studies are also needed, and that statistical analysis to evaluate changes in participants is also required. These results have both practical and research relevance. In practical terms, we offer some ideas for the design and implementation of research experiences that may be useful for curriculum developers or other university decision makers. For researchers, we propose some methodological issues that need to be considered in future studies.

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Compliance with Ethical Standards

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