

# **Professional learning and development initiatives for postdoctoral scholars**

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## **Abstract**

**Purpose:** Postdoctoral scholars are increasingly pursuing diverse career paths requiring broad skill sets. To create comprehensive professional learning and development strategies for postdoctoral scholars, a reporting of current approaches is required.

**Methodology:** This literature review is a systematic examination and synthesis of the current literature describing professional learning and development pertaining to postdoctoral scholars. The objectives and components of initiatives were extracted and narratively synthesized to identify important patterns and themes across the literature.

**Findings:** Commonalities amongst professional learning and development initiatives for postdoctoral scholars included skills development in the following areas: teaching and learning, mentorship, academic careers, academic writing, industry careers, networking, career planning, project management, time management, communication, leadership, and balancing work-life demands.

**Value:** In synthesizing the literature that describes professional learning and development opportunities for postdoctoral scholars, it is apparent that opportunities look different in every setting with no empirical evidence that one strategy is more effective than another. Given the significant resources often required to support professional learning and development initiatives, a deeper understanding of the benefits and deficiencies of various components is needed to ensure scarce resources are invested in the most effective strategies.

**Keywords:** Literature review, postdoctoral scholar, professional development, professional learning

**Article classification:** Literature review

## **Introduction**

Postdoctoral scholars (postdocs) are academics who hold doctoral degrees and are engaged in short term mentored research and/or scholarly training for the purpose of skills development prior to employment in tenure track faculty positions (Nerad and Cerny, 1999, Jadavji et al., 2016, Mitchell et al., 2013). With fewer than 20% of postdocs moving into tenure-track positions (Edge and Munro, 2015, Fuhrmann et al., 2011, McKenzie, 2007), an increasing number of postdocs are pursuing careers outside of academia (Fuhrmann et al., 2011). Postdocs have recognized the need for adequate professional learning and development opportunities to prepare for diverse careers, roles and responsibilities (Nerad and Cerny, 1999, Brownell and Tanner, 2012, Rybarczyk et al., 2011b).

Professional learning and development opportunities for postdocs may include informal or formal activities to increase knowledge, skills, and abilities to help improve performance in present or future roles (Åkerlind, 2005, Webster-Wright, 2009). The vast range of experiences can include formal structured initiatives (e.g., seminars, workshops, conferences, courses), embedded professional and self-directed learning activities (e.g., co-teaching, mentorship, group discussions, communities of practice, professional meetings, reading groups), and informal interactions with other researchers, educators, and scholars (Webster-Wright, 2009, Knight et al., 2006, Roxå and Mårtensson, 2009).

There is an array of non-scholarly information on researcher development initiatives that can be found online at both institutional and national levels. For many post-secondary institutions, research funding is dependant on demonstrating evidence of transferable skill training. In the UK, Vitae has worked across sectors to develop a Researcher Development Framework (Vitae, 2010). Although this work provides a valuable contribution to researcher development, it is not specific to the broader, non-research related skills that postdocs may need to develop for roles outside of academic settings. A recently published systematic review revealed professional learning and development had a positive impact on postdocs' teaching and learning skills, writing and publication skills, and general career

skills (Nowell et al, 2018). Other outcomes of engaging in professional learning and development included developing a community of peers with other postdocs, enhancing work-life balance, and purposefully planning for professional learning and development skills (Nowell et al, 2018). Although this systematic review addressed the impact of professional learning and development opportunities, it failed to provide adequate descriptions of professional learning and development initiatives so that others may replicate them.

To date, there is a gap in the literature synthesizing the objectives and components of professional learning and development initiatives for postdocs. Given the potential importance for postdocs to engage in professional learning and development, our aims were to build upon the frameworks and reviews of others and identify published articles that (1) described professional learning and development for postdoctoral scholars, and (2) described the objectives and core components of these initiatives. The synthesis of this literature may be useful to those looking to initiate professional learning and development for postdocs.

## **Methods**

The aim of this literature review was to identify literature describing the objectives and components of professional learning and development initiatives for postdoctoral scholars. This literature review was guided by Popay et al. (2006) Guidance on the Conduct of Narrative Synthesis in Systematic Reviews, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher, 2009), and the Enhancing Transparency in Reporting the Synthesis of Qualitative Research (ENTREQ) guide (Tong et al., 2012). Sixteen disciplinary and interdisciplinary databases were searched from the inception of each database to November 2017. These included Academic Search Complete, Business Source Complete, Biosis Previews, CAB Abstracts, CINAHL, Communication Abstracts, Education Resources Complete, EMBASE, Environment Complete, ERIC, IEEE Xplore, MEDLINE, PsycINFO, Scopus, SocIndex, and Web of Science. A search to identify grey literature (reports of studies not found in the peer-reviewed literature) was conducted by scanning

ProQuest Dissertations and Theses Global database, Trove (National Library of Australia theses/dissertations), Ethos (British Library theses/dissertations) and websites of national postdoctoral associations (Canadian Association of Postdoctoral Scholars, National Postdoctoral Association). A structured search was developed in Medline (OVID) and modified according to the indexing of other databases (Table 1). The search focused on two main concepts: postdocs and professional development. Both keywords and subject headings were included for each concept. No limitations were placed on study design, or publication year, however, results were limited to those published in English language. All reference lists of included articles were searched and Google Scholar ‘cited by’ was used to identify additional literature.

**Table 1:** Final Search Strategy for Ovid MEDLINE

Database(s): **Ovid MEDLINE(R) Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) 1946 to Present**

Search Strategy:

#	Searches
1	postdoc*.mp.
2	post-doc*.mp.
3	post-phd*.mp.
4	or/1-3
5	exp Staff Development/
6	exp Leadership/
7	exp Mentoring/
8	exp Mentors/
9	exp Teaching/
10	(professional adj1 development).mp.
11	(professional adj1 learning).mp.
12	(professional adj1 growth).mp.
13	(career adj1 development).mp.
14	(career adj1 mentor*).mp.
15	(career adj1 goal*).mp.
16	(career adj1 preparation).mp.

17 (career adj1 navigat\*).mp.  
18 (capacity adj1 development).mp.  
19 (postdoc\* adj2 train\*).mp.  
20 (faculty adj1 development).mp.  
21 (collegial adj1 mentor\*).mp.  
22 (peer adj1 coach\*).mp.  
23 coaching.mp.  
24 mentor\*.mp.  
25 (faculty adj3 learning communit\*).mp.  
26 work life balance.mp.  
27 lifelong learn\*.mp.  
28 transformative learn\*.mp.  
29 (talent adj1 management).mp.  
30 (communit\* adj1 practice\*).mp.  
31 leadership.mp.  
32 (teaching adj1 development).mp.  
33 (teaching adj1 skill\*).mp.  
34 (academic adj1 skill\*).mp.  
35 (academic adj1 development).mp.  
36 (skill\* adj1 development).mp.  
37 (training adj1 program\*).mp.  
38 (talent adj1 development).mp.  
39 (skill\* adj1 train\*).mp.  
40 (education\* adj1 development).mp.  
41 or/5-40  
42 4 and 41  
43 limit 42 to english language

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The initial search yielded 7,571 articles that were screened independently and in duplicate by two reviewers using the title and abstract to assess relevancy. Articles were excluded if they were clearly not about postdocs, and /or professional learning and development. A total of 162 papers were

identified as potentially relevant and were retrieved in full text for comprehensive review. Articles were included if the authors 1) described professional learning and development, defined as any activities and interactions that may increase postdocs' knowledge and skills, contribute to their personal, social, and emotional growth as scholars, and improve their performance in present or future roles, and 2) the professional learning and development was for postdocs. After reviewing 162 full text articles, 29 articles describing 26 different professional learning and development initiatives for postdocs were included in this review.

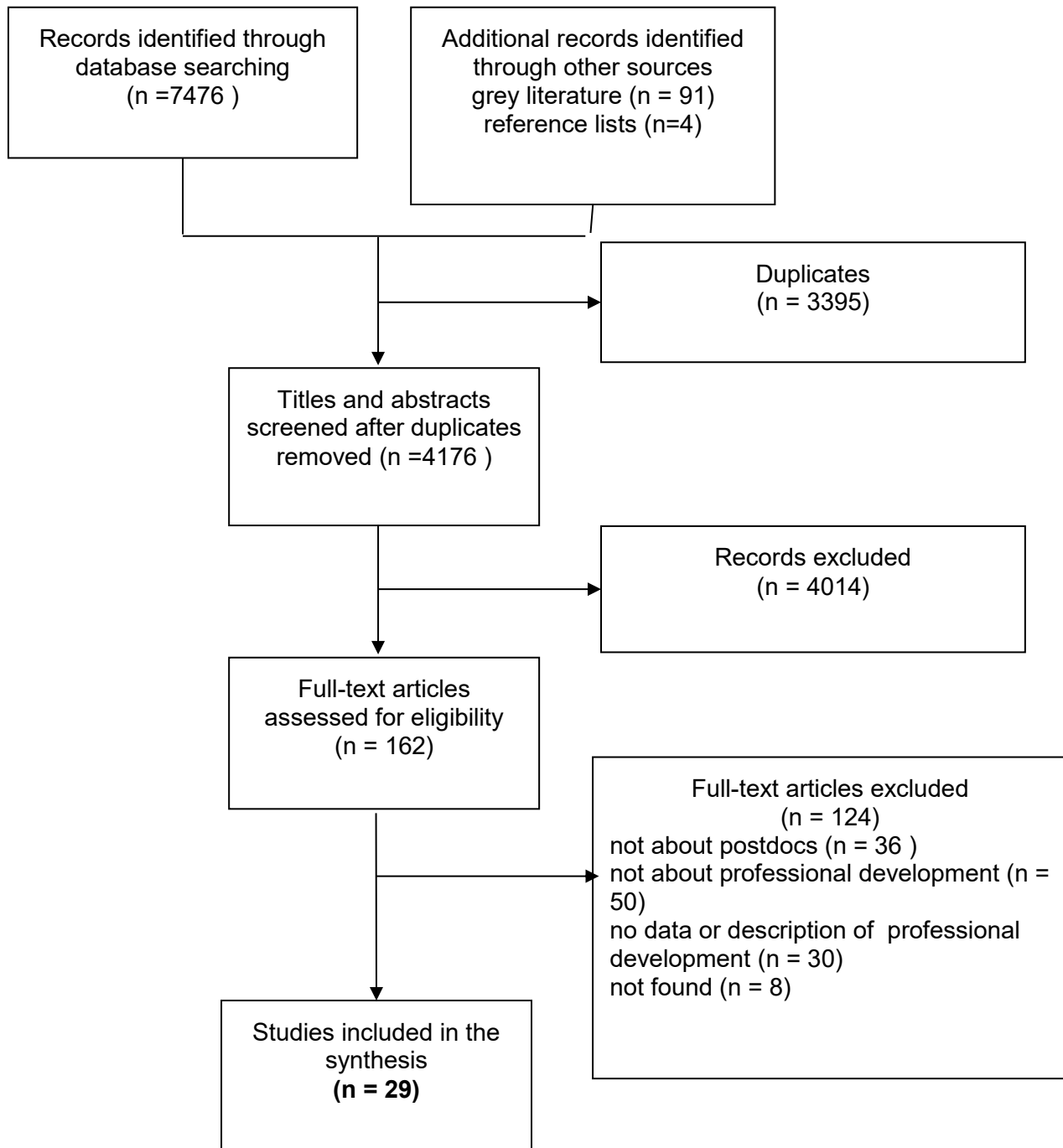
Narrative synthesis was used to synthesize the findings from the 29 articles (Popay et al., 2006). Articles were organized into groups to aid the process of description and analysis while looking for patterns within and across groupings. Both text and tables were used to illustrate common themes.

## **Results**

Figure 1 illustrates the flow of literature throughout the review. For each included article, the stated objectives and components of the professional learning and development initiative were extracted. When more than one article described the same professional learning and development initiative, the articles were combined to represent one initiative.

### **Setting and participants**

The majority of articles described professional learning and developing initiatives implemented in the U.S. ( $n = 24$ ). Literature from the U.K. ( $n = 3$ ), Africa ( $n = 1$ ) and Canada ( $n = 1$ ) were also identified. Participants in the professional learning and development were postdocs ( $n = 17$ ), graduate students and postdocs ( $n = 6$ ), faculty and postdocs ( $n = 3$ ), and graduate students, faculty, and postdocs ( $n = 3$ ).



**Figure 1:** PRISMA flow diagram

## Theories and frameworks

Six of the 29 articles included a clearly articulated theory or framework that informed the development of the professional learning initiative. Bauer et al. (2013) identified their program as an ‘authentic immersive learning’ program where postdocs engaged in learning events that purposefully created intellectual discomfort to challenge assumptions about teaching and learning. Similarly, Chang (2008) identified their program as a ‘needs-based educational format’ that unified postdocs need for guidance in producing competitive grant applications, with the knowledge and experience of a successful grant applicants to increase their confidence, skills, and ultimately improve their grant success. Two frameworks were mentioned in two different articles including the ‘how people learn framework’ (Cox, 2011), and the ‘career management framework’ (McCullough, 2010). The ‘how people learn’ framework posits an effective learning environment is simultaneously knowledge-centered, learner-centered, assessment-centered, and community-centered (Bransford et al., 1999). Knowledge-centered learning environments are those that emphasize a deep understanding of course content and an ability to apply this knowledge; learner-centered learning environments build upon students’ preconceptions, misconceptions, and ideas about course concepts; assessment-centered learning environments provide opportunities for feedback where students and faculty learn from one another; and community-centered learning environments engage students with peers and members of the community outside of the classroom (Bransford et al., 1999). The career management framework incorporates flexible career planning and support mechanisms that can be embedded into existing institutional policies and practice through downloadable tools and resources including a skills matrix, skills guidebooks, and a checklists to facilitate career tracking (Career Research Staff, 2000).

The FIRST program, described by Derting (2016) and Ebert-May (2015), was informed by learning theory, evidence-based instructional strategies, and principles of scientific teaching. The program incorporated active learning (Handelsman et al., 2004) shown to have lasting effects on



teaching practice (e.g., Gibbs and Coffey, 2004; Steinert et al., 2006) where participants were actively engaged in all dimensions of learner-centered pedagogy (Henderson, 2008).

### **Engaging minorities in professional learning and development**

Six programs focused on increasing the numbers of women and minorities engaged in professional learning and development. One program attempted to increase the quality and diversity of educational research through increased participation of minorities and women (McCullough, 2010). Other programs provided opportunities for minority and women postdocs to engage in professional development opportunities through funded fellowship programs (Golden, 1982, Bessent, 1989, Eisen and Eaton, 2017, Michigan State Univ, 1983). The third program had the goal of implementing programs that improved the climate, recruiting, and retention of underrepresented groups (Richmond, 2005) through the development and implementation of a series of professional skills workshops tailored for women chemists in academia including: 1) coaching strong women in the art of strategic persuasion; 2) a women's leadership program; and 3) launching a successful academic career in the chemical sciences.

### **Descriptions of professional learning and development initiatives**

Twenty-nine articles described 26 different professional learning and development initiatives for postdoctoral scholars (Supplementary Table 1). Although the articles varied in the degree to which they described the aims of professional learning and development initiatives and their components, several commonalities were identified across multiple programs. Table 2 offers a synthesis of professional learning and development commonalities which are presented in further detail below in order of most to least prominent.

**Table 2:** Professional Learning and Development Components

[illegible]

Michigan 1983							x			x		
Phillips 2010					x		x					
Reid 2015		x	x						x			
Richmond						x						
Rybarczyk 2016							x			x	x	
Rybarczyk 2011							x			x	x	
<b>TOTAL <i>n</i></b>	4	6	5	3	7	3	12	5	3	15	2	1

## **Teaching and learning**

Fifteen articles reported on 11 professional learning and development initiatives that focused on developing teaching and learning skills in higher education. Some targeted preparing postdoctoral scholars for the responsibilities of an academic career that balances both research and teaching (Derting, 2016, Holtzclaw, 2005, Keen-Rhinehart, 2007, Rybarczyk, 2016, Rybarczyk et al., 2011a, Bessudnov et al., 2015, Brancaccio-Taras et al., 2016, Eisen and Eaton, 2017, Levy, 2014), while others attempted to address specific teaching and learning issues such as diversity in the classroom (Baiduc et al., 2016), implementing learner-centered teaching practices (Ebert-May, 2015), or developing teaching statements (Kearns, 2011). Another program provided opportunities to actively guide inquiry into research based teaching and learning and model facilitated group instruction (Bauer et al., 2013). Two programs specifically aimed to increase the number of minorities and women actively engaged in educational research and development (Michigan State Univ, 1983, Golden, 1982).

## **Mentorship**

Providing mentorship or purposeful development of mentorship skills was an explicit component mentioned in 12 of the included articles. Mentorship was provided to strengthen career guidance (Abu-Yousif, 2010, Aschwanden, 2007, Kearns, 2011), provide direction for future faculty (Gerdeman, 2007), and to ensure postdocs had realistic yet ambitious plans while integrating into academic settings and preparing for potentially diverse career markets (Levy, 2014, Holtzclaw, 2005). Six articles focused on the professional learning and development of minorities and women, three of these focused specifically on providing mentorship (Michigan State Univ, 1983, Rybarczyk et al., 2011a, Rybarczyk, 2016) while another was designed to provide mentorship for leaders in enterprise for researchers with commercial ideas (Phillips, 2010). Other programs provided postdocs with the opportunity to develop skills in mentorship through workshops (Bessent, 1989) or engagement in a structured peer mentorship program whereby senior postdocs mentored their junior postdoc peers (Kuhn, 2016).

### **Industry career skills**

Seven professional development programs had goals of preparing postdocs for competitive careers outside of academia. Two programs provided targeted opportunities for postdocs to learn about industry careers through visiting local companies and interacting with industry scientists (Abu-Yousif, 2010, Levy, 2014) while others supported postdocs in exploring traditional and non-traditional careers including work environments, salaries, and responsibilities (Krone, 2016, Kuhn, 2016). Another initiative attempted to pilot practical training opportunities for postdoctoral fellows while assessing their employability and preparedness for a competitive job market requiring both technical expertise and practical leadership skills (Henderson, 2016). Other programs focused on helping postdocs develop skills to make them competitive for jobs outside of university settings (Phillips, 2010) and increase the number of researchers holding research positions outside the university (Lee et al., 2010).

### **Academic writing**

The development of academic writing skills was the identified goal for six of the professional development programs. Some programs included the development of writing skills as a part of a larger professional development initiative (Bessudnov et al., 2015, Golden, 1982, Reid Ponte, 2015). Two programs provided constructive feedback in a supportive environment to help improve their scientific writing, increase their confidence and skill level, and ultimately, improve their grant and publication success (Chang, 2008, Gianaros, 2006). Although Lee et al. (2010) did not mention providing feedback on writing and grant proposals, the authors did identify the program's purpose was to increase the number of publications and grants obtained by postdoctoral scholars.

### **Career planning**

Five professional learning and development initiatives assisted postdoctoral scholars in career planning and preparation (Krone, 2016, Kuhn, 2016, Levy, 2014, Mccullough, 2010). Specifically these programs were designed to help postdocs identify the best career fit for them by highlighting

opportunities inside and outside of academia, including the requirements, advantages and disadvantages of various career paths (Kuhn, 2016), sometimes through networking and receiving advice from a variety of mentors (Levy, 2014). In one program, postdocs were supported in developing a formalized career plan to help position them as independent investigators with established programs of research (Reid Ponte, 2015).

### **Networking**

Five authors described networking as being a key part of their professional learning and development initiatives for postdocs. Some programs targeted enhancing networking opportunities with the broader research community and industry partners (Abu-Yousif, 2010, Golden, 1982). Others offered seminars to help postdocs develop networking skills (Bessent, 1989, Kuhn, 2016, Reid Ponte, 2015)

### **Academic career skills**

Four articles describe professional learning and development programs that covered aspects related to successful advancement in an academic career including exposure to the scholarship of teaching and learning, issues in higher education, faculty promotion and tenure, and academic recruitment processes. (Bessudnov et al., 2015, Gerdeman, 2007, Levy, 2014). One initiative provided postdocs with the opportunity to engage in and/or observe mock interviews for faculty positions (Henderson, 2016).

### **Communication skills**

Bessudnov et al. (2015) described a professional learning and development initiative that offered a range of activities, including workshops and conferences, designed to enhance the communication and understanding of current research across disciplines. Golden (1982) described a program that provided opportunities for, and assistance in, presenting research findings in colloquia and other forums while supporting postdocs' participation in professional meetings where they could

further disseminate their work. Another author identified communication skills workshop was provided, without describing any further details (Kuhn, 2016).

### **Personal effectiveness**

Leadership skills development workshops were mentioned by Aschwanden (2007) and Bessent (1989) and Richmond (2005) described leadership training focused on positively influence the career paths women. Also included were project management sessions (Aschwanden, 2007) and professional learning and development initiatives that offered opportunities to manage larger researcher projects (Rybarczyk et al., 2011a, Rybarczyk, 2016). In addition, two authors indicated time management sessions were included (Aschwanden, 2007, Bessent, 1989) and one article identified work life balance sessions were included in the professional learning and development initiatives (Kuhn, 2016), however, no specific details about these sessions were provided.

### **Discussion**

This extensive review of literature was undertaken to explore the professional learning and development of postdoctoral scholars from inception to 2017 to synthesize descriptions and core components of initiatives. With the understanding that fewer than 20% of postdocs move into permanent academic positions (Edge and Munro, 2015, Fuhrmann et al., 2011, McKenzie, 2007), there is a clear necessity for professional learning and development opportunities aiming to prepare postdocs for diverse careers, roles and responsibilities outside of academic settings (Nerad and Cerny, 1999, Brownell and Tanner, 2012, Rybarczyk et al., 2011b). As identified in this review, the goals for professional learning and development initiatives for postdocs were most commonly related to teaching and learning skill development and mentorship. Other goals included the development of broader academic and career skills. Although several key commonalities were identified (Table 3), there is a distinct lack of description of many of the included components which made comparison and synthesis across articles more challenging.

**Table 3:** Summary of professional learning and development opportunities

<b>Common components</b>	<b>Specific component aims</b>
Teaching and learning	<ul style="list-style-type: none"><li>• Implement learner centered teaching practices</li><li>• Address specific issues in teaching and learning</li><li>• Develop teaching statements</li><li>• Guide inquiry into research based teaching and learning</li><li>• Model facilitated group instruction</li><li>• Increase minorities and women engaged in educational research and development</li></ul>
Mentorship	<ul style="list-style-type: none"><li>• Provide mentorship to postdocs to strengthen career guidance</li><li>• Provide mentorship to women and minorities</li><li>• Develop skills in mentoring others</li></ul>
Industry career skills	<ul style="list-style-type: none"><li>• Interact with industry scientists</li><li>• Explore traditional and non-traditional work environments</li><li>• Develop leadership skills</li><li>• Increase numbers of researchers in industry</li></ul>
Academic writing	<ul style="list-style-type: none"><li>• Provide constructive feedback on writing</li><li>• Improve grant and publication success</li></ul>
Career planning	<ul style="list-style-type: none"><li>• Identify career opportunities and fit</li><li>• Develop formalized career plans</li></ul>
Networking	<ul style="list-style-type: none"><li>• Enhance networking opportunities with research and industry communities</li><li>• Develop networking skills</li></ul>
Academic career skills	<ul style="list-style-type: none"><li>• Introduce scholarship of teaching and learning</li><li>• Engage in mock academic interviews</li><li>• Describe academic processes</li></ul>
Communication skills	<ul style="list-style-type: none"><li>• Enhance communication skills</li><li>• Develop dissemination skills</li></ul>
Personal effectiveness	<ul style="list-style-type: none"><li>• Advance leadership skills</li><li>• Develop time management skills</li><li>• Develop project management skills</li><li>• Address work life balance challenges</li></ul>



A recent study conducted by Welp et al. (2018) revealed that professional learning and development activities that specifically target identified needs resulted in better perceived performance and more strongly encourage encouraged reflective thinking when the activities were perceived as useful. Postdoctoral scholars are preparing for diverse career paths within and beyond academia that require broad skill sets. Higher education is called upon to provide professional learning and development opportunities that go beyond careers in academia to meet their diverse needs of postdocs. This literature review reports on the status of professional learning opportunities, and the prevalence of various components.

Continuous professional learning and development is key for today's professional workforce (Webster-Wright, 2009, Friedman and Phillips, 2004). While there is an increase in research demonstrating professional learning and development should be related to current and future practice (Garet et al., 2001) many opportunities fail to meet participants authentic needs (Gravani, 2007). Similar to the findings of Webster-Wright (2009), we found much of the literature concerning the professional learning and development of postdocs to be anecdotal in nature, describing activities and delivery methods, while failing to focus on the actual learning experiences of postdocs. Webster-Wright (2009) argued this is not surprising as to date most of the professional learning and development described in the literature is focused on the "delivery of programs rather than understanding more about the experiences of professional learning to understand it more effectively" (p.712).

Although we conducted a comprehensive and systematic search of the literature, this review is not without limitations. First, as with any literature review, it is possible not all relevant literature was captured. Further not all initiatives are written about or published. There is a vast array of non-scholarly information on researcher development programs available online and it was beyond the scope of this review to include these sources. Second, limiting the search to articles describing professional learning and development for postdoctoral scholars allowed for detailed review of initiatives and components,

but also narrowed the scope of the literature review. Third, a majority of articles were from the United States, and while this reflects the current state of literature, the geographical picture may not accurately reflect professional learning and development opportunities in the US or in other countries. Fourth, the limited depth of descriptions of professional learning and development initiatives within the articles reduced our ability to provide rich descriptions and details of initiatives. Finally, the professional learning and development components varied significantly across articles making comparison and synthesis challenging. Despite these limitations, the findings from this literature reveal valuable knowledge about the breadth and depth of professional learning and development approaches for postdocs. The findings may be used to inform the objectives of professional learning and development initiatives for postdoctoral scholars and contribute to a more rigorous approach to supporting professional learning and development.

The importance of continual professional learning and development for postdocs is recognized across disciplines and nations. Given that not all of the professional learning that is being offered is going to be described in the literature, more research across institutions is needed to accurately capture and document the current status and types of professional learning and development provided for postdocs. The outcomes of this review can inform future research including identifying the needs and experiences of postdocs engaging in professional learning and development, and how to direct resources in order to provide an optimal blend of strategies. Research can be done with postdocs themselves on the types of professional learning and development that they have found to be most beneficial and why, as well as the types of professional learning and development that they would like to have access to as they transition into diverse careers. Further research could also be conducted to explore differences between postdocs from different disciplines and the differences in developmental needs of junior and more senior postdocs as no articles reported on these topics. Finally, this review provides insight into the types of professional learning and development offered, however further research is needed to study the effectiveness of these diverse approaches and the impact on postdoc

success in future careers. We also concur with Webster-Wright (2009) that more research needs to be conducted on postdocs experience of engaging in professional learning and development opportunities.

### **Conclusion**

Our review of the literature adds to and supports previous literature on the professional learning and development of postdoctoral scholars. By synthesizing the current state of professional learning and development initiatives for postdoctoral scholars we were able to highlight different approaches and their perceived benefits, when possible. Significant resources are required to support many professional learning and development initiatives, therefore, future research is needed to understand the effectiveness of individual initiatives and their components to ensure resources are focused on the most effective professional learning and development strategies.

## References

- Abu-Yousif, A., Erik, C., Skoczinski, A., Hasan, T. (2010), The ABC's of industry: a postdoc program provides a sneak peek into industry careers. *Nature Biotechnology*, 28, 625-626.
- Åkerlind, G. (2005). Postdoctoral researchers: Roles, functions and career prospects. *Higher Education Research & Development*, 24, 21-40.
- Aschwanden, C. (2007), Transferable Skills and Portable Careers. *Science*, 316, 471-475.
- Baiduc, R., Linsenmeier, R. & Ruggeri, N. (2016), Mentored discussions of teaching: An introductory teaching development program for future STEM faculty. *Innovative Higher Education*, 41, 237-254.
- Bauer, C., Scharberg, M. & Reider, D. (2013), Transformative research-based pedagogy workshops for chemistry graduate students and postdocs. *Journal of College Science Teaching*, 43, 36-43.
- Bessent, H. (1989), Postdoctoral leadership training for women of color. *Journal of professional nursing : official journal of the American Association of Colleges of Nursing*, 5, 279-82.
- Bessudnov, A., Guardiancich, I. & Marimon, R. (2015), A statistical evaluation of the effects of a structured postdoctoral programme. *Studies in Higher Education*, 40, 1588-1604.
- Brancaccio-Taras, L., Gull, K. & Ratti, C. (2016), The science teaching fellows program: A model for online faculty development of early career scientists interested in teaching. *Journal of Microbiology & Biology Education*, 17, 333-338.
- Bransford, J., Brown, A., & Cocking, R. (2000). How people learn: Brain, mind, experience, and school. Washington, DC: National Academy Press.
- Brownell, S. E. & Tanner, K. D. (2012), Barriers to faculty pedagogical change: Lack of training, time, incentives, and...tensions with professional identity? *CBE-Life Sciences Education*, 11, 339-346.
- Careers Research Staff (CRS). (2000). "Research Careers Builder: Careers Research Staff Good Management Practice Project." [Online]. Available from: <http://gmprcs.group.shef.ac.uk/rcb.html> (accessed 6 May, 2019).
- Chang, S. H., Daniel, C., & Chamberlain, R. (2008), Works-in-progress: guiding junior scientists through career development applications. *Journal of cancer education : the official journal of the American Association for Cancer Education*, 23, 142-8.
- Cox, M. C., McNeill, N., Cekic, O., Frye, M., & Stacer, M. (2011), Assessing the Pedagogical Impact of the VaNTH Engineering Research Center on Faculty and Postdoctoral Professionals. *International Journal for the Scholarship of Teaching & Learning*, 5, 1-19.
- Derting, T. L., Henkel, T., Maher, J., Arnold, B., & Passmore, H. (2016), Assessing faculty professional development in STEM higher education: Sustainability of outcomes. *Science advances*, 2, e1501422.
- Ebert-May, D. D., Henkel, T., Maher, J., Momsen, J. L., Arnold, B., & Passmore, H. (2015), Breaking the cycle: future faculty begin teaching with learner-centered strategies after professional development. *CBE life sciences education*, 14, 14.

- Edge, J. & Munro, D. (2015), Inside and outside the academy: Valuing and preparing PhDs for careers.
- Eisen, A. & Eaton, D. (2017), A Model for Postdoctoral Education That Promotes Minority and Majority Success in the Biomedical Sciences. *CBE-Life Sciences Education*, 16, 1-11.
- Friedman, A. & Phillips, M. (2004), Continuing professional development: Developing a vision. *Journal of Education and Work*, 17, 361-376.
- Fuhrmann, C. N., Halme, D. G., O'sullivan, P. S. & Lindstaedt, B. (2011), Improving graduate education to support a branching career pipeline: Recommendations based on a survey of doctoral students in the basic biomedical sciences. *CBE-Life Sciences Education*, 10, 239-249.
- Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F. & Yoon, K. S. (2001), What Makes Professional Development Effective? Results From a National Sample of Teachers. *American Educational Research Journal*, 38, 915-945.
- Gerdeman, D. R., Arlene, A., Eikey, R. A. (2007), A Course to Prepare Future Faculty in Chemistry: Perspectives from Former Participants. *Journal of Chemical Education*, 84, 285.
- Gianaros, P. J. (2006), A Seminar on Scientific Writing for Students, Postdoctoral Trainees, and Junior Faculty. *Teaching of Psychology*, 33, 120-123.
- Gibbs G, & Coffey M (2004). The impact of training of university teachers on their teaching skills, their approach to teaching and the approach to learning of their students. *Active Learning in Higher Education* 5, 87–100.
- Golden, M. P. (1982), Postdoctoral Faculty Fellowship Program. Final Report.
- Gravani, M. N. (2007), Unveiling professional learning: Shifting from the delivery of courses to an understanding of the processes. *Teaching and Teacher Education*, 23, 688-704.
- Handelsman J, Ebert-May D, Beichner R, Bruns P, Chang A, DeHaan R, Gentile J, Lauffer S, Stewart J, Tilghman SM, et al. (2004). Scientific teaching. *Science* 304, 521–522.
- Henderson C (2008). Promoting instructional change in new faculty: an evaluation of the Physics and Astronomy New Faculty Workshop. *American Journal of Physics* 76, 179.
- Henderson, R. (2016), The Mock Academic Faculty Position Competition: A Pilot Professional and Career Development Opportunity for Postdoctoral Fellows. *Academic medicine : journal of the Association of American Medical Colleges*.
- Holtzclaw, J. D., Lee G., Pyatt, R., Giver, C.S., Hoey, J., Haynes, J. K., Gunn, R.B., Eaton, D., & Eisen, A. (2005), FIRST: A Model for Developing New Science Faculty. *Journal of College Science Teaching*, 34, 24-29.
- Jadavji, N., Adi, M., Corkery, T., Inoue, J. & Van Benthem, K. (2016), The 2016 Canadian National Postdoctoral Survey Report.
- Kearns, K. D., & Subino, C. (2011), Resources and practices to help graduate students and postdoctoral fellows write statements of teaching philosophy. *Advances in Physiology Education*, 35, 136-45.

- Keen-Rhinehart, E. S., Holzman, I., Eisen, J., Haynes, A., & Eaton, D. C. (2007), Fellowships in Research and Science Teaching (FIRST) program provides exceptional postdoctoral training in research, teaching and service. *FASEB Journal*, 21, A222-A222.
- Knight, P., Tait, J. & Yorke, M. (2006), The professional learning of teachers in higher education. *Studies in Higher Education*, 31, 319-339.
- Krone, D. W., & Thomas J. (2016), ChemIDP: mapping your career. *Chemical & Engineering News*, 94, 36-36.
- Kuhn, C. C. (2016), Boosting the career development of postdocs with a peer-to-peer mentor circles program. *Nature biotechnology*, 34, 781-3.
- Lee, L. J., Gowers, I., Ellis, L. & Bellantuono, I. (2010), Well rounded postdoctoral researchers with initiative, who are not always “tied to the bench” are more successful academically’. *International Journal for Researcher Development*, 1, 269-289.
- Levy, R. (2014), Postdoc Mentorship Can Launch Careers. *American Scientist*, 102, 418-421.
- Mccullough, H. (2010), *Using personal development planning for career development with research scientists in sub-Saharan Africa*. PhD, University of Liverpool
- Mckenzie, M. (2007), Where are the scientists and engineers? Ottawa, ON: Statistics Canada Science, Innovation and Electronic Information Division.
- Michigan State University (1983), New Paths toward Research Leadership for Minorities and Women. Final Report.
- Mitchell, J., Walker, V., Annan, R., Corkery, T., Goel, N., Harvey, L., Kent, D., Peters, J. & Vilches, S. (2013), The 2013 Canadian Postdoc Survey: Painting a Picture of Canadian Postdoctoral Scholars. Canadian Association of Postdoctoral Scholars and Mitacs.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D., And The Prisma Group (2009), Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of Internal Medicine*, 151, 7.
- Nerad, M. & Cerny, J. (1999), Postdoctoral patterns, career advancement, and problems. *Science*, 285, 1533-1535.
- Nowell, L., Ovie, G., Berenson, C., Kenny, N., & Hayden, K.A (2018), Professional learning and development of postdoctoral scholars: A systematic review of the literature. *Education Research International*, 2018, 1- 16. doi: 10.1155/2018/5950739
- Phillips, R. A. (2010), Encouraging a more enterprising researcher: the implementation of an integrated training programme of enterprise for Ph.D. and postdoctoral researchers. *Research in Post-Compulsory Education*, 15, 289-299.
- Popay, J., Roberts, H., Sowden, A., Petticrew, M., Arai, L., Rodgers, M., N, B., Roen, K. & Duffy, S. (2006), Guidance on the Conduct of Narrative Synthesis in Systematic Reviews. In: PROGRAMME, A. P. F. T. E. M. (ed.).
- Reid Ponte, P. H., Berry, D. L., & Cooley, M.E. (2015), A new model for postdoctoral training: the Nursing Postdoctoral Program in Cancer and Health Disparities. *Nursing outlook*, 63, 189-203.

- Richmond, G. L. (2005), COACHing women to succeed in academic careers in the chemical sciences. *Journal of Chemical Education*, 82, 351-353.
- Roxå, T. & Mårtensson, K. (2009), Significant conversations and significant networks – exploring the backstage of the teaching arena. *Studies in Higher Education*, 34, 547-559.
- Rybarczyk, B., Lerea, L., Lund, P. K., Whittington, D. & Dykstra, L. (2011), Postdoctoral training aligned with the academic professoriate. *BioScience*, 61, 699-705.
- Rybarczyk, B., Lerea, L., Whittington, D., & Dykstra, L. (2016), Analysis of Postdoctoral Training Outcomes That Broaden Participation in Science Careers. *CBE life sciences education*, 15.
- Steinert Y, Mann K, Centeno A, Dolmans D, Spencer J, Gelula M, Prideaux D (2006). A systematic review of faculty development initiatives designed to improve teaching effectiveness in medical education: BEME Guide No. 8. *Med Teach* 28, 497–526.
- Tong, A., Flemming, K., McInnes, E., Oliver, S. & Craig, J. (2012), Enhancing transparency in reporting the synthesis of qualitative research: ENTREQ. *BMC Medical Research Methodology*, 12.
- Webster-Wright, A. (2009), Reframing Professional Development Through Understanding Authentic Professional Learning. *Review of Educational Research*, 79, 702-739.
- Welp, A., Johnson, A., Nguyen, H. & Perry, L. (2018), The importance of reflecting on practice: How personal professional development activities affect perceived teamwork and performance. *Journal of Clinical Nursing*, 1-12.
- Vitae (2010), Researcher Development Framework, available at:  
[www.vitae.ac.uk/CMS/files/upload/Vitae-Researcher-Development-Framework.pdf](http://www.vitae.ac.uk/CMS/files/upload/Vitae-Researcher-Development-Framework.pdf)  
(accessed 6 May 2019).

**Supplementary Table 1:** Professional development program descriptions

Author/Year	Aims of the Program	Description of Professional Learning and Development
Abu-Yousif 2010	1) Strengthen career guidance and mentoring. 2) Enhance communication within the research community. 3) Provide opportunities to learn about industry careers by visiting local companies and interacting with industry scientists.	Topics covered ranged from grant writing to mentor development. A connection between postdocs and research and development companies was established.
Aschwanden 2007	Develop skills that make postdocs competitive for jobs outside of university settings and learn skills to meet industry demands.	Philadelphia Scientific Management course: four sessions split over five months including leadership skills, time management skills, project management, funding, mentoring, and landing a faculty position. Laboratory Management Institute at the University of California: a three-week intensive split into five courses: leadership, management, best practices, mentoring, and innovation.
Baiduc 2016	1) Introduce teaching and learning issues and research and identify how to use it to advance teaching practices. 2) Create discussion-based learning communities focused on instructional experiences and classroom observations. 3) Familiarize participants with issues of diversity in the classroom via readings and group discussions.	A 10-week program comprised of an orientation, three group meetings, classroom observations, selected readings on teaching and learning and meetings with faculty mentors.
Bauer 2013	1) Provide active guided inquiry into research-based teaching. 2) Uncover and challenge implicit assumptions. 3) Model facilitated group instruction.	Five instructional events occurred over 6 working hours.
Bessent 1989	1) Influence career paths by increasing personal and professional development 2) Provide new skills to improve the quality of contributions to the field	A series of seminars covering topics such as time management, assertiveness training, fiscal analysis, research, leadership, mentoring, networking, marketing, and stress management.



Bessudnov 2015	Covering aspects related to successful advancement in an academic career.	A range of activities including workshops, conferences, presentations, and communication; academic writing (publishing and grant applications); teaching; academic job market; and others (academic ethics, international comparison of academia and academic careers, etc.).
Brancaccio 2016	Prepare postdoctoral students and early career biologists for science teaching positions.	Over a five-month period, fellows participated in six webinars on topics such as metacognition, course design, developing learning outcomes, assessment methods, active learning approaches, and writing a teaching philosophy statement.
Chang 2008	Develop skills and knowledge in grantsmanship in a supportive environment by providing feedback to individuals about their proposals, increasing their confidence and skill level.	Group meeting every 2 weeks to engage in proposal presentations or workshops by experts (e.g. grant writing, scientific writing, time management, and organizing) followed by discussions about recent progress, barriers to productivity, and suggestions to overcoming those barriers.
Derting 2016 Keen- Rhinehart 2009 Eisen 2017	1) Combine intensive, formal, structured training in teaching and research with professional development, formal and informal community building, and explicit efforts to increase the diversity of the science workforce. 2) Develop and apply learner-centered teaching practices in undergraduate biology courses	FIRST fellows perform a traditional 3-year research fellowship with a research mentor, together with additional formal professional opportunities, including: 1) A semester-long course in current pedagogies and exploration of the primary literature in teaching and learning, 2) A “course-within-a-course” taught by the fellows to their peers, incorporating techniques learned, followed by peer and instructor evaluation. 3) Selection of a teaching mentor with whom the fellow develops a program of training and takes on a leadership role in teaching a course (e.g. design new courses or renovate old ones) and conducts a science education research project.
Ebert-May 2015	1) Implement learner-centered teaching practices in the classroom. 2) Design assessments that are aligned with beliefs and practices of learner-centered teaching.	A 2-year professional development program where postdocs : 1) Developed a learner-centered introductory biology course with a team of postdocs. 2) Completed an authentic teaching experience. 2) Received feedback from mentors about teaching, development of courses and teaching materials, and job applications.

Gerdeman 2007	Provide mentoring and guidance to future faculty in chemistry.	Seminars focused on exposing participants to skills and knowledge for successful faculty careers and provided a space to discuss career-related matters.
Gianaros 2006	<ol style="list-style-type: none"> <li>1) Use problem-based and collaborative learning activities to increase scientific writing skills</li> <li>2) Provide constructive feedback to help improve their peers' scientific writing.</li> </ol>	<p>Participants met weekly for 9 weeks to:</p> <ol style="list-style-type: none"> <li>1) Read and discuss principles of scientific writing</li> <li>2) Use these writing principles to provide peer feedback and revise manuscripts</li> </ol>
Golden 1982	Provide opportunities for professional development/skills enhancement, research/publication, and association to minority and women faculty employed full-time in institutions where heavy emphasis is placed on teaching and service.	Provided opportunities to improve research skills, writing skills, and presenting skills. Fellows were supported to participate in professional meetings where they could disseminate their work, expand their professional networks, and enhance their recognition in educational research and decision making.
Henderson 2016	<ol style="list-style-type: none"> <li>1) Pilot practical training opportunities for postdoctoral fellows</li> <li>2) Assess participant's employability and preparedness for a competitive job market, where recruitment requires both technical expertise and practical leadership skills.</li> </ol>	A mock academic faculty position was developed where postdocs applied, were shortlisted, and underwent the academic interview process.
Holtzclaw 2005	<ol style="list-style-type: none"> <li>1) Improve the next generation of science educators by providing both intensive mentored research and teaching experiences:</li> <li>2) Enhance the pedagogy and diversity of courses and the number of qualified underrepresented minority entering biomedical fields.</li> <li>3) Promote links between research intensive institutions leading to further collaboration in research and teaching.</li> </ol>	<ol style="list-style-type: none"> <li>1) 90-minute course on teaching covering philosophical, pedagogical, and scientific underpinnings of learning and teaching; discussions of teaching portfolios, writing of teaching philosophy statements, course and syllabus design.</li> <li>2) Fellows are matched with teaching mentors.</li> </ol>
Kearns 2011	Familiarize participants with teaching statements including the purpose, audience, content, and style of genre.	<p>Faculty mentors guide participants through an analysis of sample teaching statements including:</p> <ol style="list-style-type: none"> <li>1) Listening to a brief introduction to the purpose and audience for statement of teaching philosophy.</li> <li>2) Reading two 2-page teaching statements composed by graduate students in two different disciplines.</li> </ol>

		<ul style="list-style-type: none"> <li>2) Uncovering a list of questions to be addressed in an effective teaching statement.</li> <li>3) Assessing the extent to which each teaching statement exemplifies the qualities that search committees use to define successful statements.</li> <li>4) Practicing writing their teaching statements.</li> </ul>
Krone 2016	Assist graduate students and postdoctoral scholars in the chemical sciences with career planning and preparation.	<p>Focused on four essential components of the career development process:</p> <ul style="list-style-type: none"> <li>1) Self-assessment</li> <li>2) Skill strengthening</li> <li>3) Career exploration</li> <li>4) Goal setting</li> </ul>
Kuhn 2016	<p>To help postdocs:</p> <ul style="list-style-type: none"> <li>1) Find their best career fit by showing them scientific opportunities inside and outside of academia, as well as each career path's requirements, advantages and disadvantages.</li> <li>2) Identify and develop the skills required to advance toward the profession that best matches their career aspirations.</li> <li>3) Take responsibility for their own career development while guiding and supporting them.</li> </ul>	<ul style="list-style-type: none"> <li>1) Mentor training event to introduce mentors to the program directors</li> <li>2) Monthly meeting between mentors and mentees focused on different topics such as career development plans, self-assessment, relevant career paths in science, etc.</li> </ul>
Lee 2010	<ul style="list-style-type: none"> <li>1) Increase the numbers of publications and grants obtained by postdoctoral scholars</li> <li>2) Decrease the numbers of researchers moving from contract to contract</li> <li>3) Increase the numbers of researchers holding leadership positions outside the University.</li> </ul>	<ul style="list-style-type: none"> <li>1) Communication skills workshops included presentation skills, public communication and outreach opportunities, writing research publications, and teaching and tutoring workshops.</li> <li>2) Research environment skills workshops included writing a successful grant application, ethics and governance, an introduction to commercial skills for life scientists, and mentoring.</li> <li>3) Project management skills were developed through supervising undergraduates carrying out research for 6 weeks during the summer.</li> </ul>

Levy 2014	To mentor future faculty at teaching- and research-focused undergraduate institutions by ensuring postdocs have an ambitious yet realistic plan, receive advice from a diversity of mentors, are involved in faculty life, and are prepared for the job market.	<ol style="list-style-type: none"> <li>1) Each postdoc is assigned a research and teaching mentor</li> <li>2) In collaboration with the teaching mentor, postdocs teach different sections of the same class</li> <li>3) A different faculty member observes the class lectures and discussions so two faculty can write strong, detailed recommendation letters about the postdoc's teaching qualities from different perspectives.</li> <li>4) Each postdocs is assigned a professional development mentor who reviews their application materials, runs mock interviews, gives feedback on job talks, and discusses job negotiations.</li> <li>5) Postdocs are invited to orientation and training activities developed for new tenure-track faculty.</li> <li>6) Postdocs are encouraged to mentor a yearlong senior capstone experiences.</li> </ol>
McCullough 2010	To enhance and progress career development.	<ol style="list-style-type: none"> <li>1) A personal development action plan to record professional development goals and achievements</li> <li>2) A progress monitoring document to reflect on progress using a reflective cycle</li> <li>3) An annual report to keep track of professional development.</li> </ol>
Michigan 1983	<ol style="list-style-type: none"> <li>1) Increase the number of minorities and women actively engaged in educational research and development.</li> <li>2) Increase the quality and diversity of educational research through increased participation of minorities and women in the various educational research networks.</li> </ol>	<ol style="list-style-type: none"> <li>1) The first year included research collaboration with an experienced educational researcher, a research seminar, visiting scholars, and formal course work.</li> <li>2) The second year focused on "mentor fellow" research collaboration to ensure a continued relationship with an active educational researcher.</li> </ol>
Phillips 2010	To embed enterprise training within transferable skills training.	<p>A university wide enterprise program comprised of:</p> <ol style="list-style-type: none"> <li>1) Several speakers from different subject areas</li> <li>2) Skills training workshops to assess the commercial viability of research</li> <li>3) A mentoring program whereby a researcher could discuss a commercial idea with a member of staff and a mentor from a similar background.</li> <li>4) An annual three-day residential enterprise school to work on an idea, find real market research data, patent information, work out</li> </ol>

costs and present the idea to a panel of judges justifying a case for funding.

Reid 2015	To prepare nurse scientists for conducting independent research that advances nursing knowledge and interdisciplinary understanding of complex health issues.	The professional development and career planning component of this program provides fellows with the support and resources required to develop a career plan, establish contacts within the research community and enhance skills in grant writing and manuscript development.
Richmond 2005	<ol style="list-style-type: none"><li>1) Enhance communication and negotiation skills necessary to achieve professional goals.</li><li>2) Develop leadership techniques that are effective for women scientists in an academic setting.</li><li>3) Provide a forum for networking with other academic women scientists and engineers.</li><li>4) Develop effective strategies for making institutional and departmental change that improves the climate, recruiting, and retention of underrepresented groups.</li></ol>	<ol style="list-style-type: none"><li>1) Combine self-presentation, leadership training, and faculty development in an interactive format that encourages highly personal learning.</li><li>2) A multi-faceted approach to develop professional negotiation skills</li><li>3) A Women's Leadership Program to give participants some basic concepts and tools to further develop their leadership skills.</li><li>4) Workshops introducing mutual interest-based negotiations or solution-finding to people considering entering academic careers.</li></ol>
Rybarczyk 2016 Rybarczyk 2011	Prepare postdoctoral scholars for the responsibilities of an academic career that balances both research and teaching.	A structured three-year funded postdoctoral training program with a 75%-time commitment focused on research and a 25%-time commitment focused on a mentored teaching experience with professional development activities integrated throughout the three years including workshops and seminars on responsible conduct of research, laboratory management, budget management, grant writing, instructional technology, and career preparation skills.

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