
Building an Informal STEM Learning Professional Competency Framework

New Horizons in Adult Education
& Human Resource Development
33(1), 25-36

Joe E. Heimlich¹

Kris Morrissey²

Margaret A. Glass³

Martin Storksdieck⁴

Dennis Schatz⁵

Nancee Hunter⁶

Abstract

This article describes the process for creating an evidence-based professional learning (PL) competency framework for people working in the informal science learning field. The project reviewed PL literature, models, and frameworks. Applying what we found to a field which lacks any unified career pathways, we determined a career stage approach would be appropriate. Content--competencies, tasks, skills, and attribute— was obtained through a DACUM workshop held in three cities; each panel represented either early, mid, or mature career stages of employees from across job categories. Thirty-four panelists from 18 museums participated with 1,006 professionals in informal science education institutions participating in the verification study. Looking across these findings and the reviews done previously, we identified trajectories of competencies that changed over time. We named four domains of work and labeled the competencies across career stages for duties within each of the domains. Field testing and research revealed the framework to be valuable and applicable. This work has led to questions related to career pathways, career progression, and professionalization of the field.

A 1939 report by the American Association of Museums (AAM) argued that museum work had become a profession, work that “requires learning as well as skill, is pursued partly for the benefit of society, has other than financial measures of success, and assumes responsibilities through its practitioners as a group for ide-

¹COSI - Center for Research and Evaluation

²University of Washington

³Independent Consultant

⁴Oregon State University

⁵Pacific Science Center

⁶Portland State University

als, objectives and discipline” (Coleman, 1939, p. 143). The word “profession” continues to defy an easy definition, but most contemporary definitions describe a profession as being about specific and specialized expertise and about norms and ethical practice (Møller, 2019; Muzio & Kirkpatrick, 2011; Scanlon, 2011).

Expertise is often described as specialized complex knowledge and skills and the competency of applying them in the work environment. Competencies tied to the knowledge and skills in the field are typically learned through practice *and* education, and then often assessed or credentialed through a formal process. In the informal science learning (ISL) field, professionals do need specialized knowledge and skills but there is no formal or standardized process for learning, assessing, or credentialing the learning or the skills. The ISL Professional Competency Framework (Framework) is a research-based initiative to advance professional learning for those professionals in ISL who work in science centers, science museums, children’s museums and nature centers – the typical member organizations of the Association of Science-Technology Centers (ASTC). The development of the framework was informed by the following insights:

1. Many paths to expertise exist, and the learning paths of individuals are often highly idiosyncratic.
2. The competencies needed for employment or advancement, or the strategies for learning those competencies are ambiguous.
3. Our knowledge of professional expertise is growing, but the body of literature on museum professional learning/development appears to lag. There is not among ISL professionals do not have a shared understanding of what constitutes evidence-based practice (Johnson, 2013).
4. The role of continuing professional development for professionals such as those in informal science institutions is presently unclear (Davis, 2011).
5. Individuals seek and potentially gain ongoing professional learning and skill advancement from engaging in a PD program (Borko, 2004; Gravani, 2007).
6. Having a defined learning pathway is important for the recognition of a field as a profession and for allowing professionals to see various ways of either deepening expertise or expanding competencies for career movement (Lieberman & Wilkins, 2006).
7. Professional development is what one is offered for an individual (course, program, conference, reading, etc.) while professional learning (PL) is what one takes in and carries away with them, in essence, what they chose to learn.
8. Opportunities for professional learning based on research, the importance of reflection, and the application of new learning are integral to building capacity and contributing to advancing the ISL field (Tran et al., 2013). While there are many PD programs designed for ISL professionals as well as academic opportunities, they are not generally aligned or based on field-wide agreement on the competencies needed to practice within the field.
9. Many professional development programs are limited to a specific STEM topic of current interest, or provide a short-term experience for a narrow sector of ISL professionals.
10. Formal credentialing of career stage skills and abilities is highly controversial in the ISL field. Any framework for professionalizing the ISL field, needs to be aligned with the principles and practices of free-choices and self-directed learning.

To deal with the many factors identified above, and to integrate learning with the needs of practitioners the field should identify both technical and so-called “soft” skills required to be more effective as a professional in the ISL field. Articulating the competencies necessary for ISL work does not need to result in professional standards. Like standards, the competencies could serve as a change agent, influencing individuals’ career decisions for pathways within ISL, between ISL and other sectors, and serve as a major anchor for adjusting current practices to support ISL professionals over the long run. Unlike standards, which signal codified agreement within a field about reinforceable minimal skills, a competency-based framework does not prescribe skills or abilities a professional is required to have, but is merely suggestive, providing guidance for individu-

als and employers.

Those insights provided the process by which a competency framework for informal science learning professionals was developed. We note that we are looking both from the provision of professional development and the taking in of professional learning as the goal of the framework is to serve both the institution (PD) and the individual (PL). We start with an abbreviated look at professional learning and professional learning frameworks, and then describe the evidence-based process for building the framework.

Background

The development of the Framework was informed by the literature around professional learning and the examples of frameworks for professional learning in related fields. We start the review with looking at PL, then models of PL and PD. We turn to looking at structures of frameworks, and finally on building a framework for PL.

Professional learning

In essence, learning is about taking in data, organizing or framing the information, making meaning of the data, and then using the data to make a decision, to act, or to feel (Ardoin & Heimlich, 2015). Learning is generally accepted to be lifelong, life-wide, and life-deep (Banks et al., 2007; NRC, 2009):

1. Lifelong indicates that learning is a process that happens at all life ages and stages, and in all contexts, including professional learning. Lifelong learning also acknowledges that much of what we learn occurs beyond elementary and secondary schooling (Falk & Dierking, 2010).
2. Life-wide indicates the tremendous breadth of where learning occurs and includes individual inquiry, conferences, reading articles, colleagues, etc. Life-wide professional learning suggests that what one learns is cumulative across many experiences and occasions (Martin, 2004). Life-wide learning includes intentional engagement in different forms of learning experiences (Malcolm et al., 2003), challenging the default assumption of learning only as a cognitive act.
3. Life-deep refers to the fact that we learn and acquire knowledge and skills particularly well when and where we actually need it. It connects with professional learning, as there is academic training (deep) for many professionals before or while in the field, and there are many study groups, learning circles, coaching, and other extensive and deep learning opportunities available. Life-deep also acknowledges that all learning is influenced by one's culture, values, beliefs, and ideologies (NRC, 2009), including the culture of the profession and the field, and that learning is mostly needs-driven.

Professional learning happens across one's professional career, in many different ways, and changes as the professional's roles shift. Just as learning is life-long, life-wide, and life deep, so too is the potential and opportunities for professional learning in this era of quickly changing technologies, jobs, and careers. Research in adult learning suggests the learning exchange is influenced by three things: (a) the nature of the learners; (b) the nature of the content to be learned; and (c) the nature of the culture (context) within which the adult and the organization sponsoring the learning co-exist (Cranton & King, 2003). The necessary cultural relevance of any specific context and content to the individual adult learner (Włodkowski, 2008) suggests that any learning event is different for each adult participant, and that they will take from it what is relevant to the nature of the opportunity within their lives and needs. Frith and Reed (1982) believe the adult's life experience creates distinctive needs, attitudes, problems, lifestyle and expectations which affect the teaching/learning exchange. Beder and Darkenwald (1982) view the difference between andragogy and pedagogy as grounded in the psycho-social dimensions of learning, including power, social roles, and life stage. Professional learning amplifies some of the issues of power and life stage.

Models of professional learning and tools for professional development

There are a number of models for effective professional learning. Kennedy (2005) describes eight professional development models including (a) award-bearing model (e.g. badging); (b) deficit model (assuming low skill);

(c) cascade model (train the trainer); (d) standards-based mode (performance equality); (e) coaching/mentoring model (individual to individual or individual to small group); (f) community of practice model (process sharing); (g) action research model (study work and then determine what is needed to be learned); and (h) transformative model (uses aspects of the previous seven).

Other professional development models have some components of those described by Kennedy. For example, a model developed by Glazer and Hannafin (2006) created teaching communities in schools. The model uses a mentoring/advisor approach to working with novices to go through a four-phase transfer of knowledge and expertise. In formal education, other models of professional development include mentoring, peer observation, and coaching of beginning teachers by experienced teachers and local support groups, usually by subject matter (see, for example, Heller et al., 2012; Jimoyiannis, 2010; Knight et al., 2006). Because these types of professional development usually take place within the school day and are sanctioned by the school, participants may engage in these activities over a longer time period than would be expected with traditional professional development sessions (Garet et al., 2001).

Sometimes a professional development model may focus on one aspect of the profession rather than multiple aspects. This is the case in a professional development model, designed and tested by Posnanski (2002), with the intent to increase self-efficacy in participating teachers. This model explored two attributes of self-efficacy: the expectancy that it is possible to develop and implement a desired behavior and the belief that the behavior will lead to the desired outcome. The focus of this approach reflects the Garet et al. (2001) conclusion that good education professional development activities should result in increasing knowledge and skills, which in turn should lead to change in practice. While obvious, the conclusion did inform the development to remain practice- rather than process-focused.

Frameworks for professional learning

In museums, careers are generally emergent and often take unexpected paths with individuals in roles blending different “specific” skill-based jobs necessitating what Webster-Wright (2009) notes as the need for continual professional learning. The question of what constitutes a framework for professional learning does not have a simple answer as the literature uses learning and development in multiple ways. For this project, we chose to use definitions across the literature that offer clearer distinctions. A professional development framework is frequently used for fields where ongoing certification and professional development is mandatory and refers to a core set of features of professional development (Desimone, 2009) and offers a framework for training focused on competency (e.g. Rodolfa et al., 2005). In essence, professional development refers to the provision of workshops, training, courses, and other activities for the purpose of professionals obtaining new skills and knowledge; sometimes the development pathway is predetermined, but across cases the content is determined by the provider. PL on the other hand, refers to the learning as needed by the individual, and models of professional learning are based on ways in which individuals rather than institutions organize their learning. Our use of a professional learning framework is an acknowledgement of the individual’s professional development pathway and growth (Lieberman & Wilkins, 2006). The Framework we developed does not assume any particular form of PD and was not influenced by the desire to support particular models of PD. Instead, the Framework we set out to create was open to any form of ongoing professional learning, whether provided through formal means or through individual formats of supporting professional growth.

The literature provides recommendations for what professional learning frameworks might entail, but without great consistency in how the ideas of frameworks for professional learning emerge and indeed focus on characteristics for professional development. For example, collaborative conversations are important for adult learners, and one study (Lind, 2007) found conversations were one of the most important components of professional development. This finding is reflected in the analysis of the efficacy of many professional development programs (e.g. Garet et al., 2001; Glazer & Hannafin, 2006; Guskey, 2003; Heller et al., 2012; Mayer et al., 2005; Penuel et al., 2007). Finally, in some cases, person-to-person professional development has been shown to be more engaging and effective than professional development accessed via an online or printed source.

Adult learners bring their own individual insights, perceptions, and experiences to the table (Dadds, 2007). While professionals need to be updated with regard to professional standards, future professional learning also need to focus on a more holistic model of what a professional needs to know and be able to do. Formalized professional development courses should be considered as important, but so are the learnings that professionals

encounter in the course of life experiences. By including the informal, nonformal, incidental, and everyday learning of professionals (Heimlich & Reid, 2017; National Academies, 2018), professional development can result in a more authentic professional learning experience and this type of reflection led to the now more common term professional learning rather than professional development (Webster-Wright, 2009; Corcoran, 1995).

A field-wide, evidence-based framework for professional learning could provide a tool by which professionals are able to see the pathways possible to intentionally and strategically build the skills and knowledge needed for differing career intentions. Professional development providers could also use the framework to develop more effective professional development and professional learning experiences. Although adults often find life experiences to be useful in navigating many aspects of their daily lives, these experiences are not always sufficient in helping them in their professional lives. Being aware of a gap in their knowledge and skill sets can help adults acknowledge the need for professional learning experiences, and seek out appropriate learning experiences. The more coherence the professional can perceive between individual needs and learning opportunities in the content of their professional development, the more likely the professional is to embrace and institute any changes in behaviors and activity presented in any professional learning experience (Penuel et al., 2007).

Building a Framework for Professional Learning

The *structure* of the framework was informed by a review of other professional learning frameworks in similar fields that require complex skills and knowledge and there is no requisite or standardized training or accreditation needed to work in the field. The review included: (a) creating a protocol for searching for frameworks; (b) identifying criteria for selection of representative frameworks; and (c) a content and structural analysis of the frameworks and associated documents. Five frameworks were selected for systematic review:

- Core Facilitators Competencies Framework, developed by The International Association of Facilitators (IAF)
- Vitae Researcher Development Framework (RDF), developed in the United Kingdom to identify the knowledge and skills required of researchers and to guide their professional development.
- Evaluator Competencies for Professional Development, developed by the Visitor Studies Association (VSA).
- The Guidelines for Excellence in environmental education series developed by the North American Association of Environmental Education.
- Certification and Training Program, developed by the National Association of Interpretation (NAI).

Additional frameworks and guides were also reviewed for contextual background on frameworks.

The review was representative rather than comprehensive, meaning we did not attempt to identify every existing framework for professional learning, but the search continued until data saturation was met. Three questions were addressed by the review: (a) How are frameworks created? (b) What are the common characteristics and dimensions of professional development frameworks? and (c) What is the potential impact of a framework on individuals and the field at large?

Through this review, five key observations emerged that helped the project team consider how to create the model for representing the framework (Morrisey et al., 2016).

1. All models provided at least minimal guidance *for assessing competency* which suggests that our ISL model should at the minimum, include indicators or examples of competencies to help individuals assess and perhaps document their competency level.
2. All the models included *resources and sometimes extensive training* opportunities associated with the competencies in the framework.

3. As a field that focuses on informal learning, there is an opportunity to reinforce and advance the principles of informal learning while considering mechanisms and strategies that support without constraining the learning paths of individuals and of the field. This finding relates strongly to discussions about *certification and licensing* which was also found in the environmental education and interpretation fields.
4. Discussions and debates about the value, purpose and efficacy of professionalization have evolved in past decade, driven by changing ideas about education, new research about learning and a more diverse and global society. While there is significant research about professional development strategies in regulated fields such as medicine or education, there is very little research about self-directed professional learning. There is an opportunity for important *research on professionalization* that could advance both the fields of ISE and the broader field of formal education.
5. All models represented learning as a continuous pathway with ever deepening or increasing skills. Stages or phases of learning were often designations to provide anchors or stepping stones in a career pathway.

The content for the framework was identified through a field-wide research effort utilizing a protocol called *DACUM* (Developing A CUrriculuM). *DACUM* was developed in Canada in the 1980s as a tool for industry to improve training by having expert employees identify the duties and tasks along with the competencies (knowledge and skills) necessary to be successful in a position. It has been championed in the USA by the Center for Education and Training for Employment at The Ohio State University where they have conducted thousands of *DACUM*s and trained scores of people to conduct them (Ohio State University, n.d.). As used today, *DACUM* is a unique, innovative, and very effective method of job, and/or occupational analysis. It is also very effective for conducting process and functional analyses for clusters of jobs, fields, and roles.

The *DACUM* workshop involves a trained *DACUM* facilitator and a panel of 5-12 expert workers from the position, occupation, or other expertise related to the area of analysis. The profile chart that results from the usual two-day workshop is a detailed and graphic portrayal of the duties and tasks performed by the workers involved. Duties are defined as a unit of work and consist of a minimum of three tasks, with each task dependent upon specific skills. In addition to the development of precise duty and task statements, lists of the general knowledge and skills, worker behaviors, and optional lists including tools/equipment used, materials/supplies necessary to conduct the job, and future job trends/concerns are also identified.

DACUM is based on three logical premises:

1. Expert workers can describe and define their job/occupation more accurately than anyone else. Persons who are working full-time in their positions are the real experts on that job. Even though supervisors and managers usually know a lot about their subordinates' work, they usually lack the expertise needed for a high quality analysis.
2. An effective way to define a job/occupation is to precisely describe the tasks that expert workers perform. A successful worker performs a variety of tasks that either the customer or employer wants performed. Possessing positive attitudes and knowledge alone are not enough. Hence, finding out what the expert workers (top performers) do will give us the opportunity to prepare other experts.
3. All tasks, in order to be performed correctly demand the use of certain knowledge, skills, tools, and positive worker behaviors. While the knowledge, skills, tools, and worker behaviors are not tasks, they are enablers which make it possible for the worker to be successful. Because these four enablers are so important, considerable attention is given during the *DACUM* workshop to identifying lists of each. The project asked the question: Are there duties and tasks consistent across job descriptions of those who work with the publics in informal science learning institutions, and do those duties and tasks change during the course of a person's career? This is done as a means to think critically about the career path needs of people, rather than focusing on job specific skills and critically examine professional development for science and technology centers.

Three DACUM panels were conducted. The first was the “early stage” career panel which was held at the American Museum of Natural History. We defined “early stage” as up to 3 years of work experience within the ISL field. The second was the mid-career stage (4-9 years of job experience in the ISL field) conducted at the Lawrence Hall of Science. The final DACUM, the mature-career stage professional (11+ years of job experience in the ISL field) was facilitated at COSI Columbus. At each site, individuals were recruited through multiple institutions’ leadership who identified staff who qualified as “expert at being in the museum” for a particular career phase. The goal was to have 12 panelists at each DACUM with no more than two from any one institution.

The dates and locations for the panels dictated what institutions could be included in the process of selecting participants. Initial requests for participation were sent through the Association of Science and Technology Centers (ASTC) to its member institutions in each geographic region. Thirty-four panelists from 18 museums participated in the three DACUM panels. Under a structured, facilitated two-day workshop process, the participating panelist experts brainstormed and built a detailed storyboard/chart of duties and related tasks they perform in their job. They also recorded the knowledge and skills required for optimal performance.

The panel workshops strictly followed the DACUM process. Following the panels, draft Competency Profiles representing the duties, associated tasks, and bodies of knowledge, skills, and personal attributes were generated. This was followed by a field-wide review (distributed through ASTC) to verify the validity and completeness of the results. A survey instrument based on the DACUM results was developed to distribute to the field. The questionnaire was placed online using the online survey platform Qualtrics. The first question distributed respondents into one of the three career stages based on self-reported years of being a science-museum professional. This screen fed individuals into one of three different questionnaires which listed every task identified in the panel process by duty. The respondent was asked to first identify how important the task was for being successful in their work. This was followed by asking the respondent to rate how difficult the task was to learn. There was a combined total of 20 duties and 106 tasks verified.

For each career stage, the respondents were provided with a rank-scale matrix for 1) skills; 2) knowledge, and 3) characteristics to gauge agreement of importance. These were each followed by open-ended response opportunities for additions or challenges. The questionnaire was distributed to ASTC member institutions in autumn 2016. The first set of questionnaires was targeted toward the 19 institutions which participated in the DACUMS. Following this first distribution, ASTC gradually expanded distribution across its entire U.S. membership. A total of 1,061 professionals from science centers, science museums, natural history museums and children’s museums responded. Of these, 289 (27.2%) were museum or science center professionals for up to three years, 363 respondents (34.2%) for four through ten years, and 409 (38.6%) for 11 years or more.

Across the three stages, there was very strong agreement regarding duties and tasks, thereby verifying the DACUM and the competency profile for each stage. Skills, knowledge, and characteristics were also verified. The data show interesting variability in the difficulty of learning the tasks, however. Although most hovered around the neutral zone—suggesting it was difficult for some and easy for others, there were some tasks and duties that, though important, were seen as easy to learn while others were more difficult. This does suggest the framework is appropriate for individuals to enter at any level of existing competency to determine if they wish to go deeper into developing competencies around a task and/or duty, or if they choose to move to a different level of performance.

There were four broad conclusions drawn from this study:

1. The Competency Profiles for all three stage levels appear to be valid. All 20 duties and 106 tasks for the three Competency Profiles are verified. There was strong agreement by the 1,061 survey respondents both in means and in combined scores for wide-spread acceptance of the duties and the subsequent tasks for all three career stage profiles (Heimlich & Meyer, 2017). There were no duties or tasks suggested by the verification panel that the original DACUM panel had not considered, though some word changes and concerns have led to reframing of those duties and tasks in the Professional Competency Framework.
2. The DACUM-identified job skills, knowledge, and characteristics appear to appropriately represent the three career stages. All 31 skills, 22 knowledge sets, and 48 individual characteristics were verified. There was very strong agreement by the survey respondents both

in means and in combined scores for wide-spread acceptance of the various individual competencies required to be considered expert at being a science-museum professional at varied career stages. There were several additional individual skills, knowledge, and traits identified and those have been incorporated into the Professional Competency Framework.

3. The career-stage approach appears to be a useful construct for looking across the profession for learning pathways. There were multiple pathways where a construct such as a duty related to mission in the early career stage (0-3 years) focused on implementation, the mid-career stage (4-10 years) focused on management, and the mature stage (11+ years) focused on leadership. However, the DACUMS and verification process also revealed an alternate pathway in which the stages represented increasing spheres of influence, from a particular role within an institution (early) to the entire institution (mid) and the ISL field at large (mature).
4. Learning the unifying duties and tasks of science-museum professionals across job-specific duties and tasks appear to increase in difficulty as individuals mature in the field. It is very likely that as individuals progress through their careers, the distance from job-specific entry skills growth and key job elements are less aligned with initial training and career preparation. This was reflected in the increase in perception of difficulty of learning tasks and the increasing movement from the “doing” of the work to the managing and then leading of the work across the career pathways.

Creating a framework

Table 1: Emergent pathways

	Early Career	Mid-career	Mature career
Visitor experiences	Implement	Develop experiences	Cultivating audiences
Relationship building	Front-line/in house	Build partners to do our work better	Partnerships for development of museum
Human resources	Manage staff	Develop personnel	Manage human resources
Mission	Represent	Advance	Develop
Budget	Manage	Develop	Overall institutional budget
Operations	Abide by policies	Operational problem solving/ operational issues	Sustainability
Professional learning	Individual PL	Team level PL	Institutional PL
Direction	Forward facing/implement	Delegate	More removed
Role	See	Hear	Think
Quality performance	Evaluation object	Evaluator	Standard setting
Focus	Job	Greater knowledge, more proactive; more external	Individual as a whole
Reflect	Individual 1-1	Staff development; group	Whole and community
Focus	Audience focus	Internal focus	Ideas—how it all works

Using the findings from the DACUMs, the project team looked across the competency profiles and began to see trajectories of competencies that are present, but change over career stages. Table 1 below shows some of the ways the competency profiles revealed pathways of different roles in the same area of work.

From this work, the team used the competency profiles to create four domains of work: (a) general expertise; (b) Institutional operations; (c) Institutional impact; and (d) Job-specific expertise. The team discussed the options of career growth as a continuum of getting “better” within a competency and also being able to move from a position of having influence primarily around the work itself, to a level of career when there is more influence at a departmental or institutional level, and finally a level of a career where there is influence over the field of ISL or professional domains within ISL (such as exhibit development or museum education). Within each domain, a series of competencies were named that were present across each career stage profile, plus the competency was defined at each of the three points of career expertise.

An initial ISL Competency Framework was field-tested: interviews were conducted in which professionals in various settings reviewed the draft framework and provided structured feedback on design, terminology, clarity, and potential usefulness of the Framework, as well as resources that may be needed to operationalize the Framework within their sphere of work. Results of iterative feedback and revisions revealed that the framework was not only helpful to individuals and organizations who consider professional learning opportunities, but also helped professionals reframe the ways they created job descriptions and staffing models (Hunter et al., 2018; Wojton & Heimlich, 2016). In another application, graduate students in museology shared that the framework helped them identify gaps in their training; we also heard that the Framework for Professional Learning by ISL Professionals identified important skills that are often implicit but critical for job performance (particularly regarding generalizable skills). In workshops at national conferences, participants consistently revealed similar ways in which the framework could be used and expressed strong desire for application (Hunter et al., 2018).

Across these contexts, several consistent themes emerged around use of the framework for both organizational and individual uses. Although all participants in the studies were able to “find themselves” in the Framework, it was more difficult for those not working in the public-facing side of science centers and museums or who are less familiar with the broader ISL community to connect to the Framework (e.g., facilities or accounting staff).

Some of the potential use for the framework included revising job descriptions, aiding in staff evaluations, examining where an organization is falling short, help in the hiring process, and identifying organizational or individual PL needs. A value for both the institution and the individuals was the potential for the Framework to aid in relevant conversations among staff or team members. As hoped, individual value was seen in use for prioritization of professional development and other career-driven goals and aid in identifying skills and competencies an individual needs to work on in order to move up in their career. Overall, respondents in interviews, focus groups, and surveys all felt the framework allowed them to feel encouraged to take more initiative in terms of their own professional development.

One important finding reinforced the intended “next phase” of the project. Many of the participants in the research expressed a strong need for supplemental support materials, mechanisms, and resources for taking action on their professional learning pathways (Hunter et al., 2018). Ultimately, after extensive testing of the framework online, the beta-version of the framework was completed and the final ISL Professional Competency Framework is now available for review and use at <https://islframework.org>.

What all this means

The work on building an evidence-based framework for professional learning by ISL practitioners has revealed far greater potential for serving individuals and the field than we originally had conceived. Evidence from pilot workshops, discussion groups, forums, and presentations reveal tremendous interest in the product developed thus far and in the perceived value of the Framework, particularly if PD and PL experiences and resources become available. This work has again illustrated the great variability in career pathways for ISL professionals and the potential challenges such variability offers.

Originally, we hypothesized that an ISL Framework could leverage deeper research into the gaps between the realities and the perceptions of the competencies required on the job. As we have progressed in this work, we

have learned there are continually more questions arising around career pathways, career progression, and professionalization of the field. These questions provide a fertile ground for additional exploration, consideration, and research including deeper study into the gaps between the realities and the perceptions of the competencies required on the job.

An evidence-based professional development framework provides one approach to advancing the professional capacity of individuals and of an entire field in ways that align with evidence-based practice and the values and principles of informal learning. While there are tweaks to be done on the framework, there is much more to do on developing the necessary supports to effectively use the Framework individually, institutionally, and field-wide. It is our hope and aspiration that this research will help move the ISL field into a position of leadership in how to think about a profession for the 21st century.

References

- Ardoin, N. M., & Heimlich, J. E. (2015, October). *The importance of the Incidental: Environmental learning in everyday life*. Keynote address at the NAAEE Research Symposium, San Diego, CA.
- Banks, J. A., Au, K. H., Ball, A. F., Bell, P., & Gordon, E. W. (2007). *Learning in and out of school in diverse environments: Life-long, life-wide, life-deep*. University of Washington, Center for Multicultural Education.
- Beder, H. W., & Darkenwald, G. D. (1982). Differences between teaching adults and pre-adults: Some propositions and findings. *Adult Education Quarterly*, 32(3), 142-155.
- Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, 33(8), 3-15.
- Coleman, L. V. (1939). *The museum in America: A critical study*. American Association of Museums.
- Corcoran, T. B. (1995). Helping Teachers Teach Well: Transforming Professional Development. *Consortium for Policy Research in Education (policy brief)*.
- Cranton, P., & King, K. P. (2003). Transformational learning as a professional development goal. *New Directions for Adult and Continuing Education*, 2003(98), 31-38.
- Dadds, M. (1997). Continuing Professional Development: nurturing the expert within. *British Journal of In-service Education*, 23(1), 31-38.
- Davis, J. (2011). *Putting learning to work: Knowledge transitions from continuing professional education to museum workplaces*. [Unpublished doctoral dissertation]. University of Victoria.
- Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, 38(3), 181-199. <https://doi.org/10.3102/0013189X08331140>
- Falk, J. H., & Dierking, L. D. (2010). The 95% Solution: School is not where most Americans learn most of their science. *American Scientist*, 98(6), 486-493. <https://doi.org/10.1511/2010.87.486>
- Frith, M., & Reed, H. B. (1982). *Lifelong learning manual: Training for effective education in organizations*. Community Education Resource Center. University of Massachusetts at Amherst.
- 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(4), 915-945.
- Glazer, E. M., & Hannafin, M. J. (2006). The collaborative apprenticeship model: Situated professional development within school settings. *Teacher and Teacher Education* 22 (2), 179-193.
- Gravani, M. N. (2007). Unveiling professional learning: Shifting from a delivery of courses to an understanding of the processes. *Teaching and Teacher Education*, 23(5), 688-704.
- Guskey, T. R. (2003). What Makes Professional Development Effective? *Phi Delta Kappan*, 84(10), 748-750.

- Heimlich, J. E., & Meyer, J. (2017). *Informal STEM DACUM competency profiles: Verification report*. COSI Center for Research and Evaluation.
- Heimlich, J. E., & Reid, A. (2017) Environmental learning. In M. A. Peters (Ed.), *Encyclopedia of educational philosophy and theory* (pp. 1-6). Springer-Verlag London Ltd.
- Heller, J. I., Daehler, K. R., Wong, N., Shinohara, M., & Miratrix, L. W. (2012). Differential Effects of Three Professional Development Models on Teacher Knowledge and Student Achievement in Elementary Science. *Journal of Research in Science Teaching*, 49(3), 333-362.
- Hunter, N., Storksdieck, M., & Staus, N. (2018). *Validating an informal science learning (ISL) framework: Findings from empirical research*. Technical Report. Oregon State University.
- Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers' professional development. *Computers & Education*, 55(3), 1259-1269.
- Johnson, J. I. (2013, November/December). Learning at and for work. *Dimensions*, 15(6), 38-43.
- Kennedy, A. (2005). Models of continuing professional development: A framework for analysis. *Journal of In-service Education*, 31(2), 235-250.
- Knight, P., Tait, J., & Yorke, M. (2006). The professional learning of teachers in higher education. *Studies in Higher Education*, 31(3), 319-339.
- Lieberman, J. M., & Wilkins, E. A. (2006). The professional development pathways model: From policy to practice. *Kappa Delta Pi Record*, 42(3), 124-128.
- Lind, V. R. (2007). High quality professional development: An investigation of the supports for and barriers to professional development in art education. *International Journal of Education and the Arts*, 8(2), 1-18.
- Malcolm, J., Hodkinson, P., & Colley, H. (2003). The interrelationships between formal and informal learning. *Journal of Workplace Learning*, 15, 313-318.
- Martin, L. M. W. (2004). An emerging research framework for studying informal learning and schools. *Science Education*, 20, 283-297.
- Mayer, D., Mitchell, J., Macdonald, D., & Bell, R. (2005) Professional standards for teachers: a case study of professional learning. *Asia-Pacific Journal of Teacher Education*, 33(2), 159-179.
- Møller, A. M. (2019). Explicit professionalism. A cross-level study of institutional change in the wake of evidence-based practice. *Journal of Professions and Organization*, 6(2), 179-195.
- Morrissey, K., Gausch, K., & Schatz, D. (2016). *Characteristics and dimensions of professional development frameworks: How emerging fields of expert knowledge identify and advance the competencies of professionals in those fields. A review and comparison of professional learning frameworks*. Informal Science. <https://www.informalscience.org/characteristics-and-dimensions-professional-development-frameworks-how-emerging-fields-expert>
- Muzio, D., & Kirkpatrick, I. (2011). Introduction: Professions and organizations – A conceptual framework. *Current Sociology*, 59(4), 389-405.
- National Academies of Sciences, Engineering, and Medicine. (2018). *Learning Through Citizen Science: Enhancing Opportunities by Design*. The National Academies Press. <https://doi.org/10.17226/25183>.
- National Research Council (NRC) (2009). *Learning Science in Informal Environments: People, Places, and Pursuits*. The National Academies Press. <https://doi.org/10.17226/12190>.
- Ohio State University, Center on Education and Training for Employment. (n.d.). *DACUM Training Information*. <https://dacum.osu.edu>
- Penuel, W. R., Fishman, B. J., Yamaguchi, R., & Gallagher, L. P. (2007). What makes professional develop-

- ment effective? Strategies that Foster Curriculum Implementation. *American Educational Research Journal*, 44(4), 921-958.
- Posnanski, T. J. (2002). Professional development programs for elementary science teachers: An analysis of teacher self-efficacy beliefs and a professional development model. *Journal of Science Teacher Education*, 13(2), 189-220.
- Rodolfa, E., Bent, R., Eisman, E., Nelson, P., Rehm, L., & Ritchie, P. (2005). A cube model for competency development: Implications for psychology educators and regulators. *Professional Psychology: Research and Practice*, 36(4), 347-354.
- Scanlon, L. (2011). *Becoming a professional: An interdisciplinary analysis of professional learning*. Springer.
- Tran, L. U., Halversen, C., & Werner-Avidon, M. (2013, July/August). Professional learning through reflecting on practice. *Dimensions*, 15(4) 27-28, 33.
- Webster-Wright, A. (2009) Reframing professional development through understanding authentic professional learning. *Review of Educational Research*, 79(2), 702-739.
- Wlodkowski, R. J. (2008). *Enhancing adult motivation to learn: A comprehensive guide for teaching all adults*. Jossey-Bass Publishers.
- Wojton, M. A., & Heimlich, J. E. (2016). DACUM panels feedback: Workshop feedback. COSI Center for Research and Evaluation.