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# Exploring the Information Literacy Needs and Values of High School Chemistry Teachers

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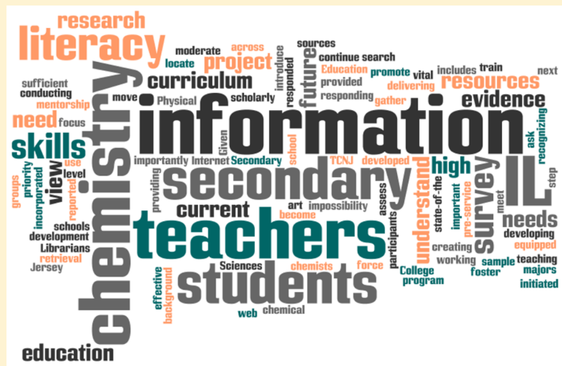


**ABSTRACT:** To meet the information literacy (IL) needs of chemistry students, The College of New Jersey's (TCNJ) Library and Chemistry Departments have created a three-year seminar with a strong IL component. The program focuses on IL skills necessary for success in industry and graduate or professional education, but may lack features specific to those students becoming secondary school educators. In order to determine whether there is a need for additions to the program, TCNJ librarians inquired about information literacy with current secondary education chemistry teachers in the United States. Through a survey, the researchers investigated the participants' perceived value of IL, the skills emphasized in high school chemistry curricula, potential difficulties in embedding IL skills, and the types of resources available to high school chemistry teachers and students. Fifty-five percent of survey participants reported that there is a moderate to high priority for IL in their chemistry curriculum. Ninety-two percent responded that students search the Internet for chemistry information. The researchers also reviewed literature about IL standards, curriculum standards in secondary education science, the importance of critical thinking skills, and the IL skills of K−12 students and teachers. The results of the survey and the review of the literature show that there is an opportunity to equip our secondary education chemistry majors with an IL pedagogy so that they can, in turn, effectively instill in their future high school students the values and habits exhibited by critical consumers of scientific information.

**KEYWORDS:** *High School/Introductory Chemistry, Chemical Education Research, Curriculum, Inquiry-Based/Discovery Learning, Internet/Web-based Learning, Problem-Solving/Decision Making, Learning Theories, Professional Development, Standards National/State*

**FEATURE:** Chemical Education Research

## ■ INTRODUCTION

According to the Information Literacy Competency Standards for Higher Education,[1] published by the Association of College and Research Libraries (ACRL), a division of the American Library Association, information literacy (IL) is the "set of abilities requiring individuals to recognize when information is needed and have the ability to locate, evaluate and use effectively the needed information." In this view, information literacy is the basis for lifelong learning and for becoming a critical consumer of information. An information literate individual is able to

- determine the extent of information needed
- access the needed information effectively and efficiently
- evaluate information and its sources critically
- incorporate selected information into one's knowledge base
- use information effectively to accomplish a specific purpose
- understand the economic, legal, and social issues surrounding the use of information, and access and use information ethically and legally.

These IL skills are not confined to any one discipline or grade level and are significant skills for individuals to adopt in our globally connected, information-rich society. Teachers are in a pivotal role to promote and model IL skills and mindsets with their students.

The Physical Sciences and Education Librarians at The College of New Jersey (TCNJ) are collaborating with the Chemistry Department to foster information literacy skills in secondary education chemistry undergraduates, helping students to become information literate teachers able to model these skills and integrate them into curriculum. The Library and Chemistry Department at TCNJ have created, and previously reported in this *Journal*,[2] a three-year seminar program to supplement the core chemistry curriculum. This is a required

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credit-bearing seminar for all undergraduate chemistry majors, including those who are chemistry secondary education majors, that has an emphasis on information literacy, good laboratory practice, and advising. However, the program may lack some features specific to those students becoming secondary school educators. Specifically, there is not a segment in the current seminar program on how to teach transferable IL skills, namely those skills that high school chemistry teachers as instructors can transfer to their students and the skills that the students could effectively employ for high school assignments, advanced secondary school courses, and undergraduate courses as a foundation for life-long learning. To begin to determine what, if anything, needs to be added to this seminar program, the Physical Sciences and Education Librarians are conducting a multistep research project. This paper discusses the first steps of that research: developing background information on the context of IL skills in the high school chemistry curricula and surveying current secondary education chemistry teachers regarding their current value of and practices with information literacy.

Given the geographic dispersion of chemistry teachers over the United States, it was not possible to conduct focus groups, which would have been the ideal way to gather this input. Instead, a survey was developed to gather information from current chemistry teachers. The survey sought input from members of the newly created national organization, the American Association of Chemistry Teachers (AACT). This organization is endorsed by the American Chemical Society and is dedicated solely to supporting K−12 teachers of chemistry. The survey was distributed via the AACT online newsletter and social media sites. Distribution was also expanded to include the listserv of the New England Association of Chemistry Teachers (NEACT).

## ■ LITERATURE REVIEW

The literature supporting and providing background information for this research program is multifaceted and includes information on the following:

- the current information literacy skill level of K−12 students;
- the current information literacy skill level of secondary school teachers;
- the link between scientific literacy and information literacy skills;
- the emphasis on standards such as the *Next Generation Science Standards* (NGSS).

Preliminary literature reviews have been completed and are reported here, but as this research progresses, there is no doubt further in-depth literature reviews will have to be performed in selected areas and that literature analyzed.

### Information Literacy Skills of K−12 Students

To understand how current secondary chemistry teachers view and incorporate information literacy skills into their curriculum, it is first necessary to understand high school students' information literacy skills. A prominent paper by Julien and Barker[3] discussed how high-school students find and evaluate scientific information. For inquiry-based scientific fields such as chemistry, biology, and physics, they noted that information literacy training was essential. This article explored the relationship between curricula in secondary classrooms intending to support development of information literacy skills and how effective the curriculum was in improving those student IL skills. The authors provided an extensive literature review and their findings confirmed a deep concern with the level of IL skills in secondary students, particularly with evaluating information and incorporating selected information into their knowledge base. Students demonstrated low level skills because they were focusing on finding the right answer while providing minimal effort. The authors reported that teachers taught to the exams and focused on substantive content rather than on information literacy skills. The authors also concluded that there is often an information literacy skills deficit among teachers themselves.

A more recent work by Smith et al.[4] confirmed that students lack the information literacy proficiencies required to succeed in the postsecondary educational environment. Gross and Latham[5] provided more validation that many students come to college without proficiency in a wide-range of information literacy skills and had an inflated view of their own abilities. The consensus in this literature was that many secondary school students lack a proficiency with regard to information literacy skills. The authors highlighted the importance for high school teachers to implement IL skills in their curricula in order to provide a baseline proficiency from which students can draw and build upon once they enter college.

### Information Literacy Skills of Secondary School Teachers

Switching the focus from students to teachers, there was literature on the need for improved information literacy skills for teachers. In one often quoted paper Crouse and Kasbohm[6] called for collaboration between teacher education faculty members and academic librarians for the development of transferable information literacy skills. Duke and Ward[7] covered Crouse and Kasbohm's work and that of many others in an extensive literature review, discussing how to prepare information literate teachers. Duke and Ward conducted a meta-synthesis of 39 related articles and book chapters. Included in the synthesis are tables on experimental design containing case studies; needs assessments; quasi-experimental studies; types of participants ranging from preservice teachers, practicum coordinators to graduate students; data sources that include pre- and postmeasurements; surveys and interviews; and summaries of the findings of the studies along with emergent themes. Detailed studies of the findings and emergent themes could provide essential guides for our future work. This review article concluded that, although significant progress has been made in addressing IL skills in the last 10 years, more needs to be done to prepare information literate teachers who can effectively teach information literacy skills and literature search strategies to their K−12 students.

### Scientific Literacy and Information Literacy

Information literacy requires critical thinking and the link between scientific literacy, which is based on a foundation of critical thinking, and information literacy has to be acknowledged and appreciated by librarians and science educators. There are many definitions of critical thinking, including Paul and Elder's[8] simple expression that it is the "ability to reach sound conclusions based on observation and information." These same sound conclusions are also needed for information literacy. Information literacy should be viewed as a fundamental way to increase and enhance one's knowledge base. Kuhlthau,[9] Small and Armone,[10] and Burdick[11] elaborated on the need to foster critical thinking skills in students along with an analysis of what motivates these students. Barranoik[12] gave a clear picture of the challenges and the difficulties motivating high school


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seniors to concentrate on understanding new ideas and adding to their knowledge base instead of just concentrating on creating a viable product. There is also work reported on increasing the critical thinking skills of the teacher, and Qing, Jing, and Yan[13] used a unique approach with preservice teachers. The authors reported promoting preservice teachers' critical thinking skills by inquiry-based chemical experimentation and noted that this resulted in significant improvement of the critical thinking skills of the preservice teachers. Hopefully, future work will answer the question if these critical thinking skills could be applied to other areas such as information literacy.

### Standards

The Framework for K−12 Science Education[14] and the Next Generation Science Standards[15] (NGSS) have far-reaching effects for education curricula since they emphasize the need for more critical thinking and more information literacy skills. NGSS is designed to bring insights into content knowledge and the ability to apply this knowledge in a world flooded with information. As stated by Cooper (ref 16, p 679−680):

> *It will no longer be possible to meet a standard solely by recall of factual knowledge. ... How students get to these end points will require the development of new curriculum materials, new assessments, and extensive support for teachers, both for those already in the field and those who are enrolled in teacher education programs. ... [The] result will be students who understand and can use their chemical knowledge.*

Appendix M[17] of the NGSS is a crosswalk between the NGSS and the Common Core State Standards for Literacy in Science and Technical Subjects. The development teams for both of these sets of standards identified "key literacy connections to the specific content demands outlined in the NGSS." In these literacy connections, such IL skills were noted:

- evaluating the validity of arguments;
- narrow or broaden an inquiry;
- gather relevant information from multiple print and digital sources;
- assess the credibility and accuracy of each source;
- integrate information while avoiding plagiarism.

This crosswalk clearly established an expectation that students will develop a proficiency around IL skills within the K−12 science curriculum.

With an emphasis on the importance of the NGSS standards, the entire March 2014 issue of *Journal of Science Teacher Education*, beginning with an editorial by Lederman and Lederman,[18] was devoted to NGSS and its implications for science teacher education. Pruitt,[19] the coordinator of the development of NGSS, began the issue with a discussion of the background, development, key aspects, and implementation challenges and opportunities. The goal of NGSS is to prepare students for college and career readiness in science, show evidence that students are able to apply knowledge, and use their grasp of scientific knowledge in new and unique situations. Krajcik et al.[20] focused on meeting the intent of NGSS and how to blend core ideas, practices, and crosscutting concepts referred to as three-dimensional learning into instruction. These three dimensions worked together to help students build an integrated understanding of a problem and develop a greater ability to solve problems, make decisions, explain phenomena, and make sense of new information.

Osborne[21] provided the rational for changes in the standards that created an improved representation of the nature of science as a social and cultural practice, enabled better communication of meaning among professional science educators, and, in turn, enabled improved classroom practice. Most importantly, the implications for teacher education were explored and teachers' needs for procedural knowledge, epistemic knowledge, and pedagogical content knowledge were delineated. Bybee[22] detailed the education shifts stressed by NGSS, as well as their implications for science teacher education. Major shifts were moving from learning facts to explaining phenomena, moving from a single dimensional science to three-dimensional science, abandoning a focus on grade level content for a progression of core ideas and practices, progressing from science as a single discipline to science/engineering, moving from science as a body of knowledge to science as a way of knowing, and moving from science as a stand-alone discipline to science connected with common core standards. Proposals to reform science teacher education were given and included revising elements of the current program, replacing components of the current program, and reforming the science teacher program.

But the NGSS were not seen as perfect and all inclusive by everyone. Talanquer and Sevian[23] critiqued the NGSS document and listed gains and losses in moving from the National Science Education Standards to the Framework for K−12 Science Education and the Next Generation Science Standards. Strengths included attempts to integrate content of science and engineering practices, interdisciplinary thinking, and a strong emphasis on modeling and argumentation as tools for building understandings. The losses included the absence of core chemistry concepts or the definition thereof. The detailed analysis was presented as a resource for K−12 teachers and curriculum developers to assist in decision-making about curriculum, instruction and assessment.

## ■ METHODOLOGY

As this research project was beginning to evolve, the American Chemical Society announced the formation of the American Association of Chemistry Teachers[24] (AACT) as a new layer of support for K−12 teachers of chemistry. Boyd[25] stated that "AACT believes by supporting teachers who first spark in students a passion for science, chemistry education is made more innovative, relevant, and effective." As Rushton[26] stated, AACT provided "a much-needed catalytic step in the shift to professional status for members of this community." AACT was the conduit for this research survey, and without their support, this work would not have commenced. The New England Association of Chemistry Teachers[27] (NEACT) also facilitated the data gathering by distributing the research survey via their listserv.

Building on the background information gained from the literature and the standards, a Qualtrics survey instrument was designed to obtain qualitative and quantitative data about the information literacy needs and values of current high school chemistry teachers in the United States. The survey, which is included in the Supporting Information, consisted of 10 multiple-choice questions and one open-ended question that focused on information literacy practices in high school chemistry curriculum, difficulties in incorporating information literacy into the high school chemistry curriculum, and information resources used in teaching high school chemistry. IL skills were enumerated as simply as possible with phrases


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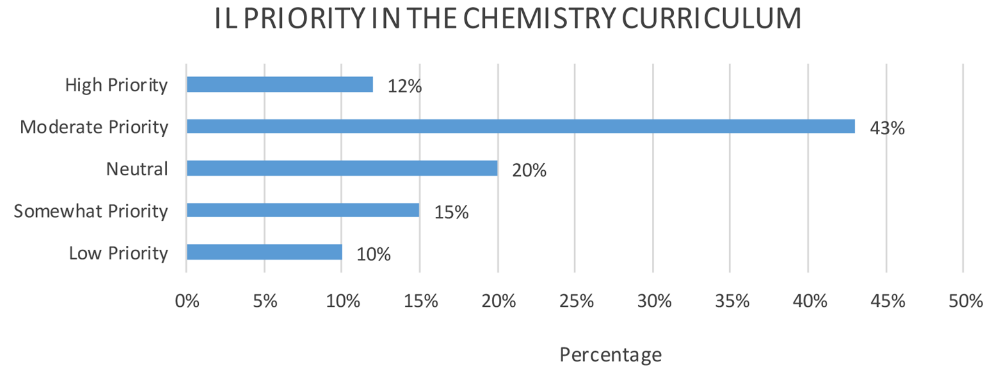


**Figure 1.** Percentage of survey participants who think information literacy skills are a priority in the high school chemistry curriculum.

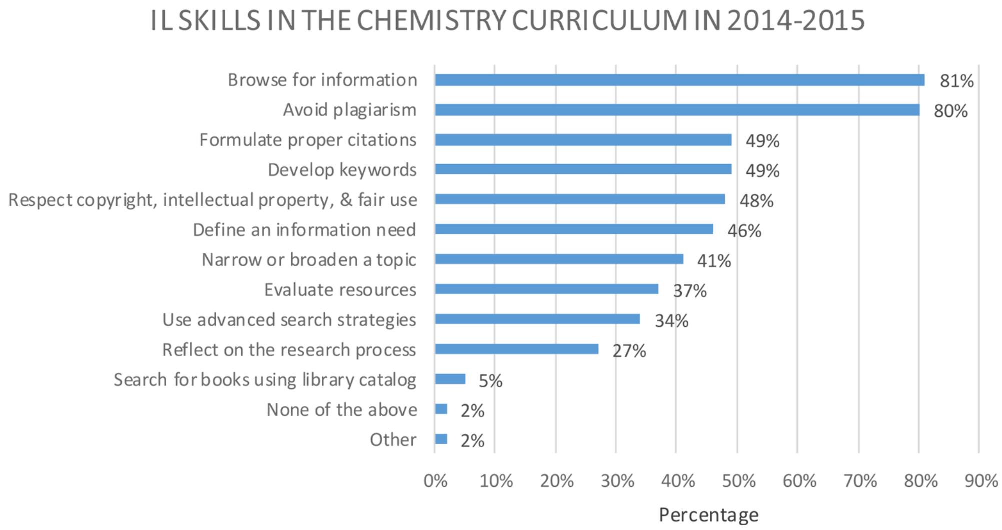


**Figure 2.** Percentage of survey participants who used specific information literacy skills in their high school chemistry curriculum during the 2014–2015 school year.

such as defining an information need, narrowing or broadening a topic, developing keywords, formulating proper citations, etc. (see Figure 2). These specific IL skills were synthesized from sources such as ACRL's Information Literacy Competency Standards for Higher Education,[1] ACRL's Information Literacy Standards for Teacher Education,[28] and the Common Core State Standards for Literacy in Science and Technical Subjects.[29] The survey was reviewed and approved by the TCNJ Institutional Review Board [IRB 1154-43].

The survey was distributed to the New England Association of Chemistry Teachers' (NEACT) listserv and via the American Association of Chemistry Teachers' (AACT) online newsletter, Facebook page, and Twitter feed. The survey called for participants who teach high school chemistry in a United States public, private, or parochial school. Because the survey was being distributed through social media and because the data will inform a research study at an undergraduate institution in the United States, it was important to establish a geographical limitation of the survey participants. Of the 99 participants who agreed to the survey's statement of informed consent, 92 participants stated that they teach high school chemistry in a United States public, private, or parochial school. This was a required question, and these 92 participants were given access to the questions in the survey. The levels of chemistry courses that participants taught include the following: Advanced Placement (51%), Honors (56%), College Prep (59%), and General (44%). Of the participants who chose Other (12%), they named or described courses such as International Baccalaureate (standard level and higher level), beyond AP level, organic, independent research, conceptual, Regents, dual-credit, and Chemistry II elective.

## ■ DATA AND RESULTS

The majority of the survey yielded quantitative data. When asked to rate the degree to which they think information literacy skills are a priority in the chemistry curriculum (Question 7), 55% of respondents noted that information literacy skills are either a moderate or high priority in the chemistry curriculum (see Figure 1). Twenty percent of participants were neutral, and 25% of respondents indicated that information literacy skills are a low or somewhat priority. In terms of establishing value, of the participants who responded to the survey, the majority acknowledged that information literacy skills were valuable to their curriculum. Additionally, 57% of respondents indicated that they have previously collaborated with a librarian (Question 11).

The survey offered respondents a list of information literacy skills found in information retrieval processes and information literacy programs (Question 4). While the list was not exhaustive in skill set, it did cover various stages of an information seeking behavior process, from identifying an information need to reflecting on the process (see Figure 2).



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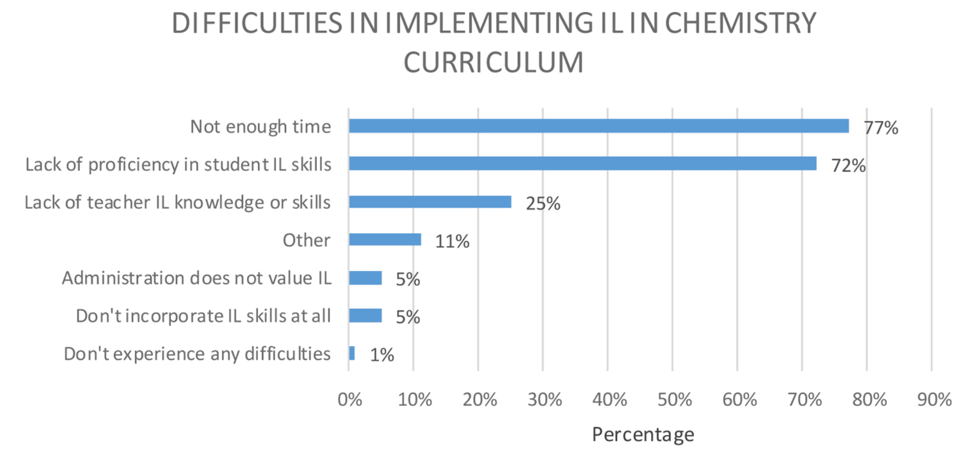


**Figure 3.** Percentage of survey participants who expressed difficulties with incorporating information literacy into their chemistry curriculum.

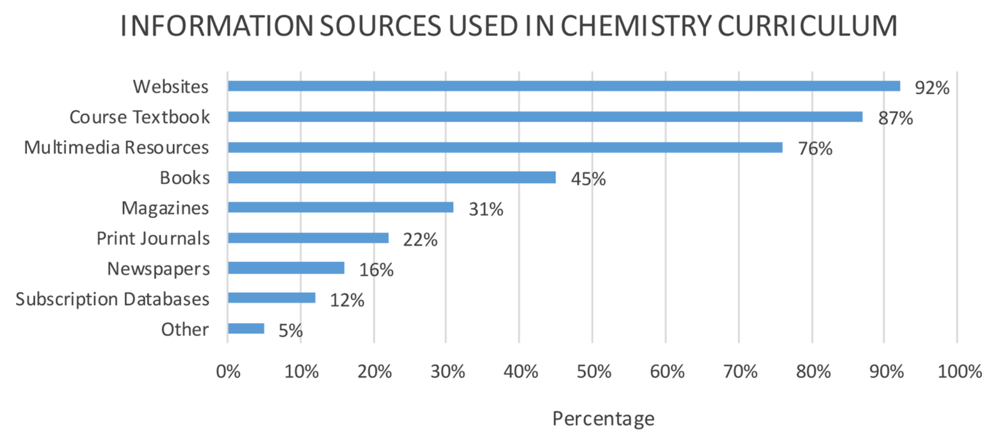


**Figure 4.** Percentage of survey participants who use various information sources in their high school chemistry curriculum.

When asked to identify the skills taught or practiced in their curriculum during the 2014−2015 school year, 81% of the participants replied that students browse resources for information, and 80% of respondents identified avoiding plagiarism as a skill they included in their curriculum. These two skills were the highest identified information literacy skills of those on the list. Other skills and responses included develop keywords (49%), formulate proper citations (49%), respect copyright/intellectual property/fair use rights (48%), define an information need (46%), narrow or broaden a topic (41%), evaluate resources for authority, relevance, currency, or bias (37%), use advanced search strategies in online search engines or in databases (34%), reflect on the information process (27%), and search for books using library catalog (5%). Two percent of respondents chose Other and noted writing-based activities such as "peer editing" and "writing abstracts for popular science articles". Additionally, 2% of the participants chose None of the above.

When discussing the barriers to incorporating information literacy skills into the curriculum (Question 6), 1% of respondents stated that they do not experience any difficulties (see Figure 3). Seventy-seven percent reported that they do not have enough time, and 72% noted a lack of proficiency in student skills. Twenty-five percent of participants recognized a lack of knowledge or skills in their own information literacy understanding, and 5% indicated that their administration does not value information literacy skills. It is important to note that 5% of participants admitted that they do not incorporate information literacy skills into their curriculum. Eleven percent chose Other and wrote in the following difficulties that were not included in the response options: access and focus on certain types of sources, lack of student interest, lack of teaching strategies, skills are taught by school librarian, too much focus on exam preparation, and lack of clear and consistent expectations.

Survey Question 8 asked participants to note the information resources they use in their teaching or ask students to use in their learning (see Figure 4). Ninety-two percent of respondents indicated that Web sites were used. In response to the follow up question "Do you ask students to search the Internet for chemistry information", 92% of respondents answered yes (Question 10). Additional information resources listed in the survey and the corresponding responses are as follows: course textbook (87%), multimedia resources (i.e., videos, illustrations, etc.) (76%), books (45%), magazines (31%), print journals (22%), newspapers (16%), and subscription databases (12%). Five percent chose Other, and one participant indicated a resource that was not included in the response options: teacher notes.

Survey Question 9 asked participants "What databases do you use in your teaching or encourage students to use?" The survey listed examples of subscription databases geared toward secondary science disciplines, other science-based subscription databases, and also free access databases online. The majority of respondents (54%) indicated that they used None of the above. Twenty-eight percent of participants stated they used free


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access databases online, such as ChemSpider. The information about databases gathered from the survey is not surprising given the cost of subscription databases. Of the 7% of respondents who chose Other, a few contributed additional database resources that were not on the survey list. Still, other contributions were a search engine (Google) and an answer engine (Wolfram Alpha), further demonstrating the use of the online information in high school chemistry classrooms.

In Survey Question 5, participants were asked to choose an information literacy skill and describe how they incorporated it into their chemistry lessons or assignments. This qualitative data not only provided specific detail on information literacy skills in the context of a chemistry lesson or assignment, but it also provided insight into the types of assignments that high school chemistry students are completing. This question was not a required question, and 33 participants responded.

Of the skills and activities that were described, participants focused primarily on the following: building background information, browsing sources for information, brainstorming and defining an information need, evaluating information, identifying key terms, avoiding plagiarism, using multiple resources, active reading, formulating a question, summarizing, presenting information, and creating proper citations in either ACS or MLA format. In some of the responses, participants described two types of information behaviors: defining key vocabulary and chemical principles, and sustained work that required synthesizing information from multiple resources. Of the participants who responded, there was more emphasis on the latter type. Additionally, there were multiple mentions of students engaging in information retrieval as an extension of laboratory experiments. At the conclusion of this experimentation, students would write lab reports. There was also mention of additional summative projects in the chemistry curriculum, such as creating a Web site, authoring a children's book or a song, writing persuasive essays or letters, writing article abstracts, and presenting information. In answering this question, two participants named resources in their responses, specifically Wikipedia and Google Scholar.

## LIMITATIONS

The findings of this survey cannot be generalized to the population of all United States high school chemistry teachers, as the survey does not claim statistical validity and because of inherent biases in the instrument. There is concern that self-reporting bias is a factor in the survey results, as participants may over or underestimate the degree to which they infuse a particular information literacy skill into their curriculum or the difficulties they encounter in incorporating them. There could also be discrepancies in participants' interpretations of these skills sets and inconsistencies in the expectations and quality they set for their students with regard to information literacy. The survey did not ask certain demographic information on these participants, such as the number of years they have been teaching and the economic or other conditions of the schools in which they teach, that could provide insight into the results. These biases and variables could impact the results of the research study. Additionally, there may be an inherent bias in that the participants who decided to take the survey were ones who identified more closely with the concept of information literacy in their curriculum.

## CONCLUSIONS

Despite the limitations of this study, there is still valuable information from the survey results. First, the study has established that most participants value information literacy in their high school chemistry classrooms. Fifty-five percent of survey respondents reported a moderate or high priority, and the survey results have shown an array of skills being incorporated into the curriculum. While the survey does not capture the quality of the instruction or assessments of these IL skills nor does it address the students' proficiencies in these skills, there exists information literacy activities, expectations, and skills in the chemistry lessons of the survey participants. An effective information literacy program for preservice secondary education chemistry majors could provide various strategies and resources, as well as address some of the concerns raised in this survey (including lack of time, level of student proficiency, lack of clear and consistent expectations) while offering an opportunity for these teacher education students to develop a proficiency in IL skills.

A significant piece of data learned from the survey is the use of online resources and search engines in the high school chemistry classroom. Ninety-two percent of survey participants responded that they ask students to search the Internet for chemistry information. The inclusion of the open web in a high school chemistry class calls for high school students to know how to effectively and efficiently search for and evaluate information for any given need. While students may be exposed to such skills in classrooms of other disciplines, it is important for them to see how information literacy skills are significant to science inquiry and chemical experimentation. And it is important for chemistry teachers to not only know how to effectively teach and assess these skills, but also to promote to their students the importance of information literacy in chemical education.

The need for the inclusion of information literacy skills in the curriculum is further emphasized by the Next Generation Science Standards. Many teachers are governed by academic standards which articulate the content students should know and the skills they should be able to do at any given grade level. Many of the IL skills documented in Appendix M of the NGSS[17] were reflected in both the quantitative and qualitative data in this survey.

This survey and literature review were the first steps in a comprehensive research study to address whether we need to foster IL skills in secondary education chemistry majors in order to prepare them to teach their future high school chemistry students. While the literature review and survey data have indicated that there is a value to focusing on the development of information literacy skills of secondary education chemistry majors in their preparation to teach high school students, more information is needed to determine what exactly this program should include to be successful. Possible next steps in the research include gathering input from chemistry professors, assessing the current IL skill sets of secondary education chemistry majors, surveying secondary education chemistry students participating in student teaching experiences, and potentially seeking input from secondary education chemistry alumni currently teaching in high schools. This research study could also benefit from a sample analysis of current high school chemistry teachers' IL instruction pedagogy and assessment methods. A review of best practices for teaching IL skills to high school science students should be completed,


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and a more thorough examination of types of information resources used in high school chemistry curricula should be conducted. Because secondary education chemistry majors have the added responsibility of effectively modeling and implementing IL skills within a curriculum, attention needs to be given to the unique role that these individuals play in the information literacy education of K−12 students.

## ■ ASSOCIATED CONTENT

### Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00450.

Survey instrument (PDF, DOCX)

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### Notes

The authors declare no competing financial interest.

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## ■ REFERENCES

(1) Association of College and Research Libraries. *ACRL Information Literacy Competency Standards for Higher Education*; Association of College and Research Libraries: Chicago, IL, 2000. http://www.ala.org/acrl/standards/informationliteracycompetency (accessed Sep 2015).

(2) Tucci, V. K.; O'Connor, A. R.; Bradley, L. M. A Three-Year Chemistry Program Focusing on Career Development Skills. *J. Chem. Educ.* **2014**, *91*, 2071−2077.

(3) Julien, H.; Barker, S. How High-School Students Find and Evaluate Scientific Information: A Basis for Information Literacy Skills Development. *Libr. & Inf. Sci. Res.* **2009**, *31*, 12−17.

(4) Smith, J. K.; Given, L. M.; Julien, H.; Ouellette, D.; DeLong, K. Information Literacy Proficiency: Assessing the Gap in High School Students' Readiness for Undergraduate Academic Work. *Libr. & Inf. Sci. Res.* **2013**, *35*, 88−96.

(5) Gross, M.; Latham, D. What's Skills Got to Do With It? Literacy Skills and Self Views of Ability Among First-year College Students. *J. Am. Soc. Inf. Sci. Technol.* **2012**, *63*, 574−583.

(6) Crouse, W. F.; Kasbohm, K. E. Information Literacy in Teacher Education: A Collaborative Model. *Educ. Forum.* **2005**, *69*, 44−52.

(7) Duke, T. S.; Ward, J. D. Preparing Information Literate Teachers: A Metasynthesis. *Libr. & Inf. Sci. Res.* **2009**, *31*, 247−256.

(8) Paul, R.; Elder, L. *A Thinker's Guide to Scientific Thinking Based on Critical Thinking Concepts & Principles*; Foundation for Critical Thinking: Tomales, CA, 2008.

(9) Kuhlthau, C. C. *Seeking Meaning: A Process Approach to Library and Information Services*; Ablex: Norwood, NJ, 1993.

(10) Small, R. V.; Armone, M. P. *Turning Kids on to Research: The Power of Motivation*; Libraries Unlimited: Engelwood, CO, 2000.

(11) Burdick, T. Pleasure in information seeking: Reducing information aliteracy. *Emergency Librarian* **1998**, *25*, 13−17.

(12) Barranoik, L. Research Success with Senior High School Students. *Sch. Libr. Worldw.* **2001**, *7*, 28−45.

(13) Qing, Z.; Jing, G.; Yan, W. Promoting Pre-service Teachers' Critical Thinking Skills by Inquiry-based Chemical Experiment. *Procedia-Social Behav. Sci.* **2010**, *2*, 4597−4603.

(14) National Research Council. *A Framework for K-12 Science Education*; The National Academies Press: Washington, DC, 2012. http://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts (accessed Sep 2015).

(15) NGGS Lead States. *Next Generation Science Standards: For State, by States*; The National Academies Press: Washington, DC, 2013. http://www.nap.edu/catalog/18290/next-generation-science-standards-for-states-by-states (accessed Sep 2015).

(16) Cooper, M. M. Chemistry and the Next Generation Science Standards. *J. Chem. Educ.* **2013**, *90*, 679−680.

(17) NGSS Lead States. APPENDIX M − Connections to the Common Core State Standards for Literacy in Science and Technical Subjects. In *Next Generation Science Standards: For States, by States*; The National Academies Press: Washington, DC, 2013. http://www.nap.edu/openbook.php?record_id=18290&page=493 (accessed Sep 2015).

(18) Lederman, N. G.; Lederman, J. S. The Next Generation Science Standards: Implications for Pre-service and In-service Science Teacher Education. *J. Sci. Teach. Educ.* **2014**, *25*, 141−143.

(19) Pruitt, S. L. The Next Generation Science Standards: The Features and Challenges. *J. Sci. Teach. Educ.* **2014**, *25*, 145−156.

(20) Krajcik, J.; Codere, S.; Dahsah, C.; Bayer, R.; Mun, K. Planning Instruction to Meet the Intent of the Next Generation Science Standards. *J. Sci. Teach. Educ.* **2014**, *25*, 157−175.

(21) Osborne, J. Teaching Scientific Practices: Meeting the Challenge of Change. *J. Sci. Teach. Educ.* **2014**, *25*, 177−196.

(22) Bybee, R. W. NGSS and the Next Generation of Science Teachers. *J. Sci. Teach. Educ.* **2014**, *25*, 211−221.

(23) Talanquer, V.; Sevian, H. Chemistry in Past and New Science Frameworks and Standards: Gains, Losses, and Missed Opportunities. *J. Chem. Educ.* **2014**, *91*, 24−29.

(24) Bodner, G. M. Creation of an American Association of Chemistry Teachers. *J. Chem. Educ.* **2014**, *91*, 3−5.

(25) Boyd, A. M. American Association of Chemistry Teachers: A New Layer of Support for Teachers of Chemistry. *J. Chem. Educ.* **2015**, *92*, 201−202.

(26) Rushton, G. From Occupation to Profession: A Perspective on the American Association of Chemistry Teachers. *J. Chem. Educ.* **2014**, *91*, 8−9.

(27) New England Association of Chemistry Teachers. http://neact.org/ (accessed May 2015).

(28) Association of College and Research Libraries. *ACRL Information Literacy Standards for Teacher Education*; Association of College and Research Libraries: Chicago, IL, 2011. http://www.ala.org/acrl/sites/ala.org.acrl/files/content/standards/ilstandards_te.pdf (accessed Sep 2015).

(29) Common Core State Standards Initiative. *Common Core Standards for English Language Arts & Literacy in History/Social Sciences, Science, and Technical Subjects*; Council of Chief State School Officers (CCSSO): Washington, DC, 2010. www.corestandards.org (accessed Sep 2015).



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