Inorganic Chemistry

VIEWPOINT

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Inorganic Chemistry and IONiC: An Online Community Bringing Cutting-Edge Research into the Classroom

Elizabeth R. Jamieson,[*,†] Hilary J. Eppley,[‡] Margret J. Geselbracht,[§] Adam R. Johnson,[⊥] Barbara A. Reisner,[¶] Sheila R. Smith,[‖] Joanne L. Stewart,[#] Lori A. Watson,[▽] and B. Scott Williams[◆]

[†]Department of Chemistry, Smith College, Northampton, Massachusetts 01063, United States

[‡]Department of Chemistry and Biochemistry, DePauw University, Greencastle, Indiana 46135, United States

[§]Department of Chemistry, Reed College, Portland, Oregon 97202, United States

[⊥]Department of Chemistry, Harvey Mudd College, Claremont, California 91711, United States

[¶]Department of Chemistry and Biochemistry, James Madison University, Harrisonburg, Virginia 22807, United States

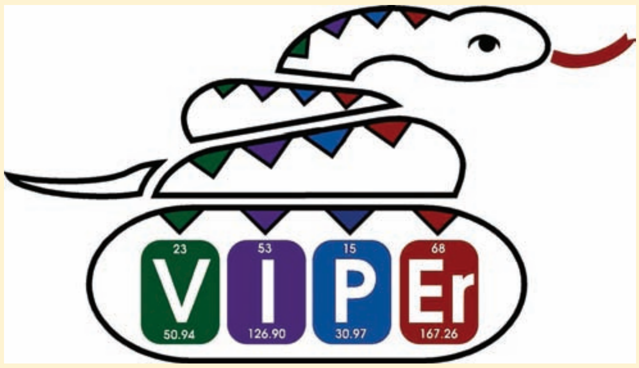
[‖]Department of Natural Sciences, The University of Michigan—Dearborn, Dearborn, Michigan 48128, United States

[#]Department of Chemistry, Hope College, Holland, Michigan 49422, United States

[▽]Department of Chemistry, Earlham College, Richmond, Indiana 47374, United States

[◆]Joint Science Department of the Claremont Colleges, Claremont, California 91711, United States

ABSTRACT: This Viewpoint highlights creative ways that members of the Interactive Online Network of Inorganic Chemists (IONiC) are using journal articles from *Inorganic Chemistry* to engage undergraduate students in the classroom. We provide information about specific educational materials and networking features available free of charge to the inorganic community on IONiC's web home, the Virtual Inorganic Pedagogical Electronic Resource (VIPEr, www.ionicviper.org) and describe the benefits of joining this community.



INTRODUCTION

In a sense, inorganic chemistry is the central science of chemistry, which itself is considered the central science. Inorganic chemists work on research challenges that involve all areas of chemistry and are at the interface to other scientific fields. Both articles in *Inorganic Chemistry* and its Forums[1] demonstrate how inorganic chemistry can be used to address some of the most pressing challenges of our time. Whether the problem involves making new materials for use in solar cells, using inspiration from nature to convert methane to methanol, or developing metal-based pharmaceuticals and catalysts, inorganic chemistry is fundamental to the solutions. In order to keep abreast of the new and exciting developments in our field, we, as professional chemists, routinely browse the table of contents, get ASAP updates, or subscribe to RSS feeds of the most important journals. By perusing the table of contents of the first issue of *Inorganic Chemistry* in 2011, one learned about the potential for using organorhodium complexes to treat breast cancer,[2] how it was possible to observe reversible oxidation at a Ti^{IV} center,[3] and how designing oxides that contain Mn^{3+} in trigonal-bipyramidal coordination could be applied to making intensely colored blue pigments.[4]

Imagine for a moment how powerful it would be to give undergraduate students a sense of the excitement that we feel when we read about the latest research in our field or subfield. Think about how much more relevant and engaging learning inorganic chemistry could be if we show students how the fundamental principles they are learning in their courses are used to solve important problems. Inorganic chemists are now doing this: applying best practices in teaching and learning to bring the excitement of inorganic chemistry research into the classroom.

The Interactive Online Network of Inorganic Chemists (IONiC) was formed by a group of faculty to enhance the inorganic chemistry classroom and laboratory experience for students and faculty members. In this Viewpoint, we showcase examples of how participants in the IONiC community have incorporated current research from *Inorganic Chemistry* into their teaching to create meaningful learning experiences for students that will engage them with what is new, exciting, and relevant in

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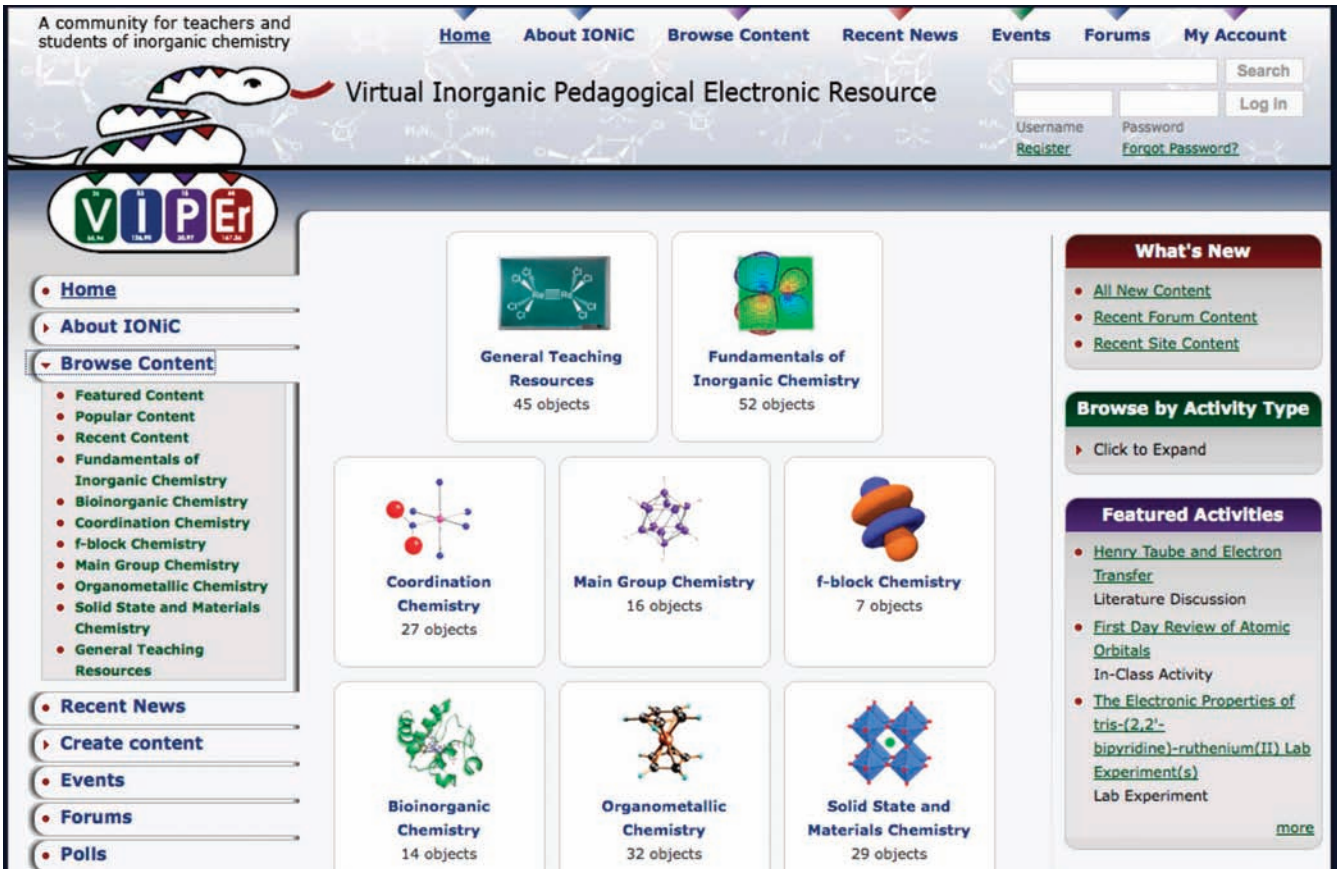

Figure 1. Screenshot of the VIPEr Home Page (www.ionicviper.org) illustrating the site's classification of different subdisciplines of inorganic chemistry, the number of LOs categorized under each topical heading, and several featured activities that illustrate the different types of LOs available on the site.

this field. All of the course materials described have been published as learning objects (LOs), small self-contained materials for teaching and learning, on the Virtual Inorganic Pedagogical Electronic Resource (VIPEr), a Web site that is the online home of IONiC (www.ionicviper.org, Figure 1).[5] These materials are available free of charge. This article also describes VIPEr's social networking features, which are designed to bring inorganic chemists together, and illustrates how contributing content based on your research can yield professional benefit and help to build a pipeline of informed and engaged undergraduate students.

■ USING *INORGANIC CHEMISTRY* IN THE CLASSROOM

Imagine that it is the first day of undergraduate inorganic chemistry. The professor walks in and writes across the board "What is inorganic chemistry?" The students work in small groups to develop definitions and articulate possible subdisciplines of the field. "The study of all the elements except carbon," answers one group, only half joking. How can the professor quickly capture the breadth and excitement of inorganic chemistry for these novice learners? VIPEr has one answer. The professor provides access to recent issues of *Inorganic Chemistry* and asks the students to look at the table of contents and graphics to refine their definitions. After examining the contents of these issues, students express surprise at how many different topics are included under the umbrella of inorganic chemistry. This hypothetical scenario describes what happens during the Introducing Inorganic Chemistry—First Day Activities "in-class activity"-type LO contributed by Barbara Reisner of James Madison University.[6] The motivation behind this assignment was to find a way to get students excited about the course right from the start and to give them a sense of the diversity of the field. It illustrates a creative use of *Inorganic Chemistry* in the classroom.

As will be described in more detail below, a tangible benefit to posting LOs on VIPEr is the ability to receive direct feedback on your work through the commenting and ratings features on the site. This particular LO quickly generated a series of comments in response, yielding a dialogue among inorganic chemists about different things they had tried in order to engage and excite students during their first class meeting. Some of these respondents indicated that they had used this particular LO, adding practical implementation notes like tips on easy ways to print the journal table of contents as well as commenting on ways they had adapted this activity. For example, in one class, students were asked to note what topics and themes they had expected and not expected as they examined the table of contents. In another class, students were asked to work in small groups to associate each article with a particular subdiscipline of inorganic chemistry based only on reading the title of the article (an educational bonus: underscoring the value of a well-crafted title!). In a follow-up activity, these students were invited to view the online graphic images associated with the titles and identify at least three examples where "the picture" changed their view of the topic

Table 1. Different Types of LOs Available on VIPEr

activity type	description
Five Slides About	Five Slides About provides an introduction or overview to a special topic in inorganic chemistry. Posted LOs range from overviews of how to teach a subdiscipline to practical examples of specialized topics.
In-Class Activity	These are short assignments designed to take up one class period or less and engage students actively in the learning process. These range from group problem solving to the even more "active" chemistry scavenger hunts and role playing.
Lab Experiment	Laboratory LOs on the site run the gamut from 1 week, 3-h laboratories to longer multiweek student-designed projects based on the primary literature. Some require significant use of specialized handling techniques and equipment. Student handouts, equipment lists, and suggestions for implementation are included.
Literature Discussion	In-class discussions and homework assignments are linked to a paper in the primary literature. Typically, a set of guiding questions, an answer key, and instructor implementation notes are provided.
Problem Set	This section is a repository of questions that can be used for problem sets, exams, and/or in-class "clicker questions". Questions range from skill-building activities to interpretation of data from the inorganic literature. The questions are restricted to registered users with confirmed faculty status.
Textbook	Reviews of textbooks for use in the core inorganic chemistry course or special topics course or books that might be of interest to an audience teaching or taking inorganic chemistry.
Web Resources	Links to and descriptions of Web sites useful for teaching all levels of inorganic chemistry are provided. Some LOs provide detailed descriptions of resources including recommendations on using the resource, while others provide only a link.

of the article. This very simple use of the journal introduces the frontiers of research into the undergraduate classroom on day one and excites and engages students to learn more about inorganic chemistry.

Perhaps a more traditional use of *Inorganic Chemistry* in the classroom is to use an article from the journal as the topic for a literature discussion. As many of us who have tried this kind of activity with undergraduates can attest, it is often challenging to find a paper that generates a rewarding class discussion, especially in an introductory level class. Here is another area where the resources found on VIPEr can be of use. There are currently 20 different "literature discussion"-type LOs on the site that come from a range of different subfields and that are appropriate for different course levels. These activities provide guiding questions for students that carefully scaffold the reading of the paper so that students can grasp the important inorganic concepts that are described. As with all LOs, each has been posted by a faculty user and tested in the classroom and is accompanied by helpful implementation notes. Comments from users add to the richness of information available about how an article was received by students.

The Tetrahedral Tellurate LO, posted by Margret Geselbracht at Reed College, is an example of a literature discussion based on an article from *Inorganic Chemistry*.[7] This assignment, given early on in the semester in a sophomore-level class, asks students to read a communication by Konaka, Ozawa, and Yagasaki[8] and to answer a series of prediscussion questions. The 50-min class discussion covered the differences between communications and full papers, the essentials of X-ray crystallographic information, multinuclear NMR, and the periodic trends described in the paper. The user-generated comments for this LO not only reaffirmed the accessibility of this paper for students but also highlighted connections that could be made to topics taught in general chemistry such as the best way to draw a Lewis structure, electronegativity and its effect on acid−base chemistry, and whether the reaction described is enthalpy- or entropy-driven.

A paper in *Inorganic Chemistry* can also provide the basis for a problem set or exam question. This may follow naturally from an in-class literature discussion, as one user pointed out in the comments to the Tetrahedral Tellurate LO. Alternatively, one could use such an assignment as a way to show students that they have the skills necessary to analyze real molecules from the literature. An example of this latter type of problem can be found in The Unusual Cation with a Xe−N Bond problem set LO.[9] In this exercise, students are asked to predict the structural features of the unusual $[F_3S{\equiv}NXeF]^+$ cation, reported in a paper by Smith, Mercier, and Schrobilgen,[10] as well as the general features of its ^{19}F and ^{129}Xe NMR spectra.

While this question was originally designed for students to solve in groups during class discussion time, VIPEr users have commented on how they have adapted it for other purposes. One professor used it as an exam question to tie into an extensive unit on multinuclear NMR in an upper-level class. Another professor focused on the cation's structural properties and used it as inspiration for a question on Lewis structure and VSEPR on an introductory chemistry exam. These examples demonstrate how a single journal article can be an inspiration for problem set or exam questions at a variety of levels in the chemistry curriculum.

WHAT YOU CAN FIND ON VIPEr

The previous examples of *Inorganic Chemistry* in the classroom illustrate some of the kinds of LOs available on the VIPEr site. Each LO on the site is self-contained and includes a description of the activity, implementation notes for the instructor, student handouts, and any other necessary materials. The majority of the LOs on the site engage student learning in an active way, and authors are encouraged to highlight the learning goals of each activity and include assessment strategies and assessment results that demonstrate student learning. Our goal is to populate the VIPEr site with exemplary LOs that will improve student learning and span the subfields of inorganic chemistry.

Table 1 lists the different types of LOs that can be found on VIPEr. These activities span the subdisciplines of inorganic chemistry: coordination chemistry, main group chemistry, *f*-block chemistry, bioinorganic chemistry, organometallic chemistry, and solid-state and materials chemistry. The LOs on the site are contributed by verified, registered faculty users, and thus the materials come from a select group of users who are already engaged in teaching chemistry at their home institution and that

Table 2. Authors Are Asked To Classify the Content Covered in Their LO by Selecting Predefined Tags

Subdiscipline	General Teaching Resources; Bioinorganic Chemistry; Coordination Chemistry; *f*-block Chemistry; Fundamentals of Inorganic Chemistry; Main Group Chemistry; Organometallic Chemistry; Solid State and Materials Chemistry
Course Level	First year; Second year; Upper division
Topics Covered	Acid−base chemistry; Bonding models: Discrete molecules; Bonding models: Extended systems; Computer modeling; Descriptive chemistry; Diffraction; Electron transfer; Electronic spectroscopy; Electronic structure; Extended structure; Group theory and applications; Kinetics; Molecular structure; Nomenclature; Periodic trends; Physical methods/analytical techniques; Physical properties; Reaction mechanisms; Symmetry; Synthesis and reactivity; Thermodynamics; Chemical literature; Communication skills; Professional skills development
Prerequisites/ Corequisites	Biology; General chemistry; Organic chemistry; Physical chemistry: Quantum mechanics; Physical chemistry: Thermodynamics

have a demonstrated interest in pedagogy by their participation in the VIPEr site. The Leadership Council of IONiC has representation from all of the various inorganic subdisciplines. Through their own contributions and by encouragement of submissions from colleagues in their subdisciplinary specialties, this organized distribution of expertise promotes a rich diversity of LOs across the different subfields of inorganic chemistry.

Each of these teaching resources is shared under a Creative Commons license,[11] allowing the author to specify the copyright terms of the LO. In most cases, this means that LOs can be modified as long as the users acknowledge the source. Most LOs are in easily editable forms (.doc, .ppt, etc.) so that users can adapt them for their own purposes.

Because of the diversity of contributions to the site, LOs are organized and sortable both by the type of LO (e.g., Lab Experiment) and by the subfield of inorganic chemisry. A traditional search box, located in the upper right-hand corner of each page on VIPEr, can be used to search the titles and descriptions of each LO. When LOs are submitted, authors are asked to use defined tags to identify their submissions with a suggested course level, topics covered, and prerequisites/corequisites. A list of predefined tags is provided in Table 2. Each of these defined tags is a hyperlink that can be used for browsing to similarly categorized activities from individual LOs. With the next major upgrade of the site, we will allow VIPEr users to enter their own user-defined tags, which will also be searchable. In addition, LO authors and the IONiC Leadership Council can insert specific links for each LO to other Related Activities on VIPEr that might be of interest as a follow-up or companion activity.

■ A WEB 2.0 ENABLED COMMUNITY

A guiding principle in designing the VIPEr Web site was to make it more than just a structured repository for teaching materials. Consequently, several social networking features have been incorporated into the site. An important part of the feedback mechanism on the site is the commenting feature and an anonymous rating system (rate from one to five *d*-orbitals!) that allows users to describe their modifications of an LO or highlight things that worked particularly well (or not) with the implementation in their class. This process was highlighted above in the description of our featured LOs in which user comments led to dialogue among educators and ideas about how to adapt various LOs to different levels in the chemistry curriculum. It works in a similar way to the rating and commenting schemes available on most commercial Web sites. People who purchase items online benefit by seeing the ratings and comments that other users post. By reading several of these, consumers can see if the item they want to purchase has performed as expected, below expectations, or exceeded expectations. Similarly, the dynamic rating/commenting system on VIPEr provides users with a way to find exemplary learning materials on the site that suit their needs.

In addition, the Forums on VIPEr allow members of the community to have a dialogue on various teaching and research issues they may be facing. The Forums cover everything from Course Content discussions to threaded discussions on Demos and Great Inorganic Quotes. Registered users of the site can post responses within Forums or create new Forum topics. For example, imagine that you wanted to find a good resource for illustrating symmetry and group theory in your inorganic course or you wanted to know the best way to keep pyridine dry for your experiments. One way to find an answer might be to ask a colleague down the hall or send off an email to the chemists you happen to know well. VIPEr offers an alternative solution to this problem. By posting your question to a Forum on VIPEr, you tap into a network of inorganic chemists around the world who are able to offer advice. This immediate access to other professional chemists is particularly helpful if you are from a smaller institution or simply do not have your own individual network of chemists to consult. The Forums illustrate the power of how social technology can be used to reduce geographic isolation and allow members of a disciplinary field to share their collective expertise.

■ CURRICULAR SUPPORT ACROSS SUBDISCIPLINES

The undergraduate inorganic chemistry curriculum varies widely between different colleges and universities. While some institutions offer only a single foundational course in the discipline, other schools are able to offer multiple courses including special topics courses. Regardless of the class organization, instructors are charged with not only presenting fundamental principles but also providing some sense of the vast breadth of our field, which, according to the ACS Committee on Professional Training, is not possible to cover in a single course.[12] This issue can be particularly challenging because most of us specialize in only one subfield and yet are expected to teach all of them. On top of all this, to fully engage students, it is important to show them what is exciting about inorganic chemistry and to make a case as to why this field is relevant to them. While we may be good at doing this in our own research area, it is certainly harder to accomplish in areas far outside what we do.

IONiC's vibrant and open community addresses curricular issues that arise due to specialization and breadth. Importantly, VIPEr is more than just a Web site where you can download LOs from different inorganic subfields. The collaborative, social networking features on the site, described in detail above, provide the accompanying support necessary for faculty to successfully

Table 3. Recommended Information for Submission of VIPEr LOs

title[a]	
Categories*	Subdiscipline; Course Level; Topics Covered
Categories	Prerequisites; Corequisites
Description	A brief description of the activity
Learning Goals	A description of the skills or content knowledge students will develop as a result of the activity
Equipment Needs	Instrumentation and supplies required for lab experiments
Related Activities	Links to other LOs on VIPEr related to the submitted activity
Implementation Notes	Helpful hints or notes on using the LO in the classroom (i.e., how you use it in your own class)
Web Resourses	Links to online resources such as journal articles, tutorial sites, etc.
Evaluation	Evaluation Methods (How do you assess student learning or performance?); Evaluation Results (Report how your students performed including typical responses, misconceptions, etc.)
File Attachments	Files typically uploaded include the LO itself and solutions/key; journal articles and other published material may not be uploaded to VIPEr
Creative Commons License*	A way to share your work while retaining copyright

[a] Only fields marked with asterisks are required.

implement LOs from outside their primary field of specialization and to expose their students to a broader range of topics in inorganic chemistry.

■ BECOMING A VIPEr USER: WHAT'S IN IT FOR YOU?

Benefit 1: Quality LOs You Can Use in Your Classroom VIPEr is a location to obtain high-quality teaching modules, from a broad range of inorganic chemistry topics that are readily adaptable for your classroom. The LOs on the site are designed and tested by other educators, and many have built-in information on the assessment of student learning outcomes. As demonstrated by the LOs featured in this article, the materials on VIPEr can assist you in finding new ways to incorporate current research in inorganic chemistry into your classroom and should allow you to expand your course offerings in areas outside your own subdiscipline.

In order to highlight additional LOs focused on bringing current research in inorganic chemistry into the classroom, we have created a Forum topic on VIPEr on this subject. In the initial post, we provide links to the LOs featured in this Viewpoint as well as to several others focused on bringing primary literature into undergraduate courses. This Forum discussion is a starting point for those who want to begin using these kinds of literature-based activities in their teaching, and we hope it will generate useful discussions among educators teaching at various institutions.

Benefit 2: Providing Broader Impact for Your Research. As chemists, we actively seek opportunities to discuss our research, and it is very likely that you are already bringing aspects of your own research into the classroom. This may be in the form of a mini-lecture, a paper discussion, an in-class activity, or a question on a problem set or exam. If this is something you are already doing, why not consider sharing that activity with the larger inorganic chemistry community?

Submitting a LO based on your own research is an easy, straightforward way to achieve "broader impact" for your work. Once you are a registered faculty user, simply click on the type of LO you wish to create under the "Create content" menu on the left side of the VIPEr home page. This will bring up a form to classify and describe your LO. To make it easy to submit, only minimal information about your LO is required (Table 3). However, richer descriptions facilitate searching, browsing, and later adoption of a LO by more users. Files can be uploaded under the "File attachments" menu, and LOs can be linked to related activities on VIPEr or other Web resources. You will be asked to choose a Creative Commons license[11] that describes the conditions under which others can copy and distribute your work; we recommend an "Attribution Non-commercial Share Alike" license that allows others to remix and reuse your work as needed with appropriate credit given to you as the author. Further instructions can be found on the VIPEr Web site.[13]

Once your LO has been posted on VIPEr, you can obtain both qualitative and quantitative data to assess the broader impact of your research-based LO. From the user comments and ratings, it is easy to get a sense of how well received a LO is within the community as well as the types of institutions being impacted by your contribution. Features built into the site allow members of IONiC's Leadership Council to keep track of how many times files from a particular LO have been downloaded (though not the identity of the downloaders). Upon request, we will share this information with the LO authors so that they can demonstrate the full impact that their research contribution has made. In addition, we have featured LOs from VIPEr in the column "JCE VIPEr: An Inorganic Teaching and Learning Community" in the *Journal of Chemical Education*.[14] Abstracts in this feature column are listed in the *J. Chem. Educ.* table of contents. We have established a relationship with *J. Chem. Educ.* that will allow us to more broadly disseminate the best LOs on VIPEr to chemistry educators across all disciplines of chemistry.

In addition to the tangible benefits of having reportable data on the impact of your LO, VIPEr also provides an opportunity to connect with students from around the world while they are still deciding what research questions appeal to them. By showcasing your research through materials presented on VIPEr, you can tap into and educate a pool of potential graduate students who are informed and excited about inorganic chemistry.

Benefit 3: Connecting You and Your Students to a Network of Faculty. Becoming a user on VIPEr provides access to a worldwide network of inorganic chemists. These connections can alleviate the professional isolation felt by faculty at smaller institutions and have also been useful for faculty in larger departments who wish to help graduate students and postdocs enter the world of academia. IONiC, through the VIPEr site, provides a link to a community of faculty leaders dedicated to teaching. One way to help graduate students interested in an academic career make professional connections is to encourage them to tap into this network of inorganic chemistry faculty. Through the interactive Forum features on the site, future and junior faculty can ask questions and get advice from more experienced chemists from around the world.

VIPEr: A RESOURCE FOR BUILDING THE INORGANIC COMMUNITY

Exposing students early and often to the most recent advances in inorganic chemistry, to the next big questions, and to the most recent answers is a logical, effective way to build and maintain a pipeline of well-informed undergraduates who are interested in adding their own contributions to the field. This task cannot be accomplished completely from textbooks and laboratory manuals. What better way to train the future inorganic chemists than to draw from the minds and energy of the current inorganic chemistry practitioners, namely, you! This task is, of course, enormous, but we believe the inorganic chemistry community can rise to it, and we believe that VIPEr serves as the ideal resource to make it happen. We encourage you to contact any of the authors of this Viewpoint if you would like more information. Or better yet, visit www.ionicviper.org and see what's there. We invite you to come for the content but to stay for the community.

AUTHOR INFORMATION

Corresponding Author
*E-mail: ejamieso@smith.edu.

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