Chapter 9

Creation of Academic Social Networks (ASNs) for Effective Online eLearning Communities

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College courses with a history of large enrollment sizes, such as General Chemistry, often rely on online homework systems to provide students with practice in applying new concepts to solve problems. Online homework systems offer many potential advantages, including instant feedback to students, adaptive learning capability, and valuable data to instructors that help identify learning obstacles on-the-fly. However, there does not currently exist network infrastructure that allows a global community of online learners to leverage this wealth of data, which may be generated from different online systems, in order to facilitate synchronous interactions, enable higher cognitive skills to be exercised, and enhance team learning in cyberspace. We have recently developed a framework for the creation of a new networking paradigm to build effective online learning communities: Academic Social Networks (ASNs). The framework integrates several key components: problem template engines (PTEs) that generate questions or exercises that test specific learning objectives, a critical skills network (CSN) that established an underlying fingerprint for each problem that is generated, and a virtual classroom environment (VCE) that allows synchronous interactions to take place in order to enable problem solving and team learning in cyberspace. These components act together to create an environment where students can work problems in order to assess mastery of specific learning objectives. Mastery is

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tracked at various levels of difficulty that are determined by the set of required critical skills needed to solve each problem. In this way, the CSN provides the foundation for which problems can be connected to one another, mastery of learning objectives can be tracked, and specific learning pathways can be analyzed. A student struggling with a problem that is testing a specific learning objective can reach out to the ASN to connect with other students that have demonstrated mastery of that learning objective at the same difficulty level or higher, and that have a track record at effective peer-mentoring, in order to get help. Ultimately, this framework allows for the development of a tool that leverages the power of large enrollments to facilitate on-demand peer mentoring and delivery of custom instruction at scale. This work represents a significant advance in the development of novel online instructional technology that has promise to create new types of effective online learning communities that improve the quality of education. This may have a profound impact on how we connect with students enrolled in the growing massive open online courses (MOOCs) or those enrolled in large gateway courses at a university.

Introduction

Each semester at the Rutgers University − New Brunswick Campus, General Chemistry hosts over two-thousand students, many of whom are in their first year. Often described as a gateway course, it serves as a requirement for the majority of STEM majors and pre-professional health students (*1*). General Chemistry is notoriously difficult, and traditionally sees a large percentage of students who are unsuccessful (e.g., either receiving a grade of D or F, or else withdrawing from the class), at least in their first attempt (*2*–*5*). This is particularly true of female and minority students (*3*, *4*, *6*). This is one of the contributing factors to the high attrition rates of STEM majors that are being experienced nationwide (*4*, *7*, *8*). The situation has become considerably challenging to address in the face of increasing enrollments for which institutional resources such as classrooms, labs, and instructional staff are often unable to keep pace. Hence, there is great need to develop new types of infrastructure that offer cost-effective, scalable solutions, and new paradigms that allow the quality of education to improve as enrollment numbers increase.

In this chapter, we report the first results for the development and implementation of a framework for creation of academic social networks (ASNs) that offer a potentially powerful solution to the challenge of improving the success rate and quality of education in large enrollment gateway STEM courses. The implementation of this project took a phased approach. In the first phase, we launched an exploratory project to create an adaptive eLearning system for chemistry which allowed students to work towards a set of learning objectives, while being given some amount of guidance to help them achieve these goals.

Learning objectives were assessed via customized problems delivered by Problem Template Engines (PTEs) that were driven by a network of chemical databases. Each problem that gets delivered by a PTE is characterized by a set of elemental critical skills required for its proper solution. The global array of critical skills is used to form an underlying Critical Skills Network (CSN) that allows problems with similar critical skill footprints to be connected to one another in a meaningful way. In the second phase, we implemented our first virtual classroom environments (VCEs) in order to tackle the pressing issues with our General Chemistry recitations. Recitations at Rutgers are meant to serve as small group learning sessions where concepts taught in class are applied to practical examples in an array of different contexts. However, due to issues regarding space and resources, student scheduling conflicts, transportation issues, and our ever-increasing enrollment numbers, there were hard limitations as to the number of students that could be accommodated in a given semester. In the fall semester of 2013, General Chemistry shifted to a completely online, virtual recitation environment. Students were able to choose their own schedule, attend multiple recitations per week, and receive individualized quizzes and prompt feedback.

While the VCEs and eLearning systems have great potential for students in and of themselves, a secondary benefit comes from the tremendous amount of data collected. This data can be as broad or as fine-grained as desired, and includes both academic data, such as content knowledge and mastery, as well as statistics surrounding participation patterns and engagement levels in the VCEs. All of this data may then be summarized to a more useable form, and build upon an individual student's profile. It is this profile that can help link a student to their peers, whether within their own classroom or not. These components culminate into our ultimate vision of the ASN. This network serves to establish a community of students who wish to share and build their knowledge through helping others. In the end, we anticipate that both the learners and the helpers of the community will reap the benefits of such interactions.

General Chemistry eLearning System (GCeLS)

Addressing the Need

Homework is an opportunity for students to apply their knowledge gained from class and refine their problem-solving skills. Our General Chemistry students are typically given homework each week, to be done on their own time by a specified due date. This homework is given and completed via an online system, simply due to its convenience when working with such a large population. All students receive the same assignment, regardless of their professor, consisting of pre-made questions as selected by one of our instructors. Because all students take the same midterm and final exams, this seemed like the fairest way to account for any slight differences in the way that professors deliver the information to their classes. However, after thinking about our students and their individual needs, we wondered if this method was truly ideal. What if students could learn the same material, but in their own way?

Metacognition is often defined as “thinking about one’s own thinking” or the ability to reflect on one’s thought processes (*9*). Students who practice successful metacognition are shown to perform better (*9*, *10*). Unfortunately, unless students have been explicitly taught in a way that fosters metacognitive processes, such as through continuous reflecting, they may lack these abilities (*5*, *9*, *11*). A common complaint our instructors hear come from students who claim to be putting in the time, but not seeing positive results on the exams or quizzes. We suspected this was not due to a lack of hard work, but rather the lack of efficient work. Do our students know how to study? Are they able to recognize what they know, what they need help with, and how to obtain the missing pieces? The literature – as well as our intuitions – pointed towards no (*5*, *12*). Our students who are struggling may be unable to monitor their thoughts and methods in an effective way.

From our observations, we considered the two problems above to come up with a single solution. We wanted students to make their own paths towards learning, but because many may lack the metacognitive skills to do so, they needed some guidance. Ideally, we needed a system that was able to “understand” students and assess what they knew, while also providing a logical pathway for them to take. But before it could teach our students, we had to teach the system. Not only did it need to know when a student was wrong, but it needed to be able to pick out why the student was wrong. It would need to be able to bring students to a level where they could learn the missing concepts. Thus, everything needed to be arranged in a specific hierarchy. And of course, the system needed to be appealing. It had to be simple to set up, yet customizable for instructors, while also engaging and user-friendly for students. With these components in mind, we set out to create the General Chemistry eLearning system (GCeLS).

Approach and Development

In the first step, the system had to contain the information needed to give and solve problems. Starting from essentially nothing, this was a major undertaking. Information had to be stored in the databases in such a way that the different components could be connected. For example, an element table would hold information concerning each element, such as molar mass, density, thermodynamic data, etc. Then a compound table could be linked to the element table, allowing for an automatic calculation of the molar mass of each compound, based solely on the elements that it contains. A compound table could be linked to a reactions table, and so on. While figuring out the best way to enter data and connect the tables was a bit of a trial-and-error process, it was well-worth it in the long run. Once the databases could feed off of each other, generating chemical equations and other calculated data could be done automatically, even when raw data was changed or added. This allowed for simple, automated construction of a problem. Figure 1 illustrates this organization.

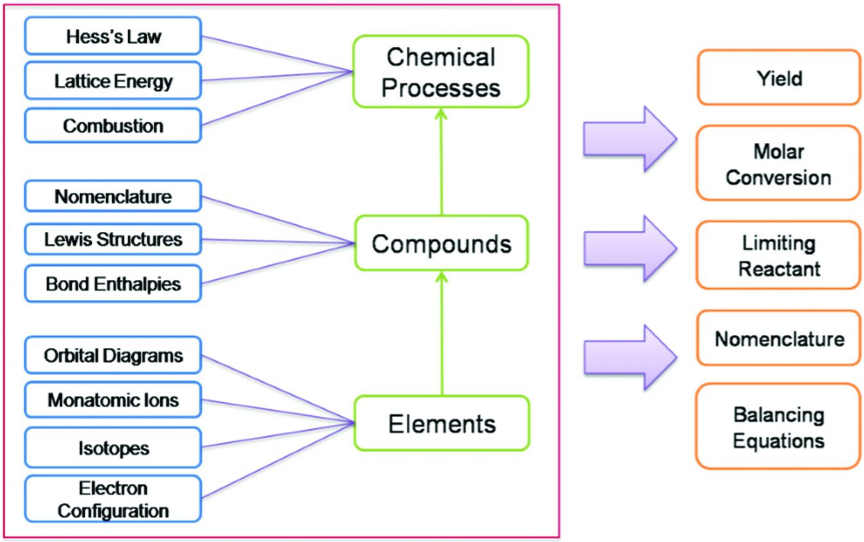

Figure 1. This overview of data organization shows how foundational aspects can ultimately feed into useable questions for students.

In the next step, we needed a hierarchy to arrange these problems. It was decided that instructors should be able to organize problems based on either the textbook that they are currently using, or by topic (regardless of the textbook). General Chemistry courses typically cover the same material, so the data would remain the same – only the organization would change. In the case of organization by textbook, the highest level would be the chapter. Chapters are typically arranged into several sections, so that became the next level. On the other hand, without a textbook, problems were instead arranged by topic first, and then by sub-topic, essentially mimicking the textbook model. After these two levels, the remainder of the hierarchy was identical.

Following the two uppermost levels, we begin to dig closer into the actual material. At the heart of the entire system live the learning objectives. These learning objectives are the simplest goal that a student can achieve, which can actually be measured. For example, a learning objective might be:

> *Student can mathematically relate theoretical, actual, and percent yield to one another.*

What we are trying to measure is whether or not, given two of the variables above, the student can solve for the third. Ultimately, our goal is to easily and accurately pinpoint conceptual holes, without mistaking them for underlying issues. This is the essence of the entire system: if the learning objectives are testing the most basic knowledge of an idea, then the system can determine whether or not a student knows what we want them to know. Of course, issues of validity will be addressed in the near future.

While we subscribed to the notion of using learning objectives, we also recognize that not all learning objectives are created equally. For example, consider the following two learning objectives:

Student can define kinetic energy

Student can mathematically relate an object's kinetic energy to its mass and velocity

While the first learning objective seeks a definition, considered rote knowledge, the second learning objective wants to know if a student can apply that knowledge to solve numerical problems involving kinetic energy. When it comes to assigning problems, we thought that it might be helpful to actually classify them according to these levels. While these issues came about naturally, Bloom's taxonomy seemed like a perfect match. We opted to use the revised taxonomy, which substitutes the noun-based nomenclature for verbs (*13*). Granted, most of our learning objectives appeared to fall under the "Remember" or "Apply" categories, with some in the "Understand," it has opened up a door for us to try and create questions that explore areas requiring higher-cognitive abilities, and that are also suitable to our system. Not only did this classification help us, but we believe that making the students aware of these levels may prove beneficial to them as well (*14*). While this is certainly an area worth pursuing, it has not been our main focus at the moment. Rather, it is something we will continue to work on in our next phase.

Once we established a set of learning objectives, the next hurdle was to translate them into a useable form. PTEs churn out the actual problems that students see. PTEs are not static, however. Within a given PTE, the problem can be manipulated. For example, the known and unknown variables can be swapped, such that a single PTE can produce two problems that ask for different variables. Alternatively, a given PTE could easily change the numbers and units associated with each variable. When giving a velocity, the system has the ability to turn out an infinite amount of numbers, in meters per second, miles per hour, feet per second, etc. Of course, this meant that each PTE had to be "told" what numbers or units are reasonable. In other cases, we had to define a relationship between the variables. For example, in searching for the velocity of an ejected electron, the value of the threshold frequency should always be less than the value given for photon frequency. Once these relationships and constraints were established, however, the system automatically followed these rules for all problems.While algorithmic problem manipulation has been seen before, it is still unclear whether or not it actually improves students' metacognitive skills and content knowledge (*11*). Still, we thought it would be useful for students to see how the same question could be asked in multiple ways, as it could help alleviate the notorious issue of "plug-and-chug." Rather than pattern-searching, students would have to actually consider the variables at hand, and then determine the missing piece.

Aside from manipulating a problem, the difficulty of each problem could be adjusted such that students need to perform extra steps to achieve an answer. A yield problem at the most basic level could, for example, explicitly state the actual and theoretical yields of a reaction in moles. To find the percent yield, students only need the relationship between the three variables. We needed problems that were not only more interesting, but could test the student at a higher level for a given learning objective. How else could this problem be asked, while still testing the original learning objective?

This is where the idea of critical skills came into play. Rather than explicitly stating the theoretical yield, students could determine this variable by themselves from a balanced chemical equation and a starting amount of a reactant in moles. For this to happen, students must understand stoichiometric conversions. When the "Stoichiometry" critical skill is turned on, this is how the problem will be given. Alternatively, students may need to perform a grams-to-moles conversion, or balance the chemical equation themselves. All of these additional steps are called critical skills, and can be tuned to adjust a given PTE. Some PTEs have few possible critical skills, while others have many. As students progress in the course, critical skills may be added to test newer knowledge. While other online programs claim to allow for similar customization or randomization, our program's design is such that it will lead directly to the seamless integration with the ASN, which will be discussed later in this chapter. Additionally, it is through the integration of critical skills into our PTEs that allow for instructors to be able to customize their assignments on a very fine-grained level.

Critical skills serve two main purposes, but we will only discuss the first at the moment. It has been shown that students commonly view chemistry as a disconnected series of facts, and often have difficulty applying identical skills across multiple topics (*15*). For example, students may learn stoichiometry in the chapter on thermodynamics, and later on in the chapter on electrochemistry, without realizing that the underlying skills apply in the same way. By involving the same critical skills throughout various topics, students may see how these skills are consistent and independent of context. It allows them to continually apply old knowledge to new situations, thus strengthening their old knowledge and forming more connections.

This organization achieves two of our goals: to allow instructors to have as much or as little customization as they desire, and to allow students to be guided down a custom path to achieve the various learning objectives. In the first, instructors may choose to have their homework correspond to a particular textbook, or they can simply select the topics. If they wish, they can go down the list even farther, selecting by subtopic, learning objective, or even PTE. They may choose to exclude certain material or critical skills.

On the flip side, the pathway a student takes to achieve a learning objective is completely dependent on what they already know. Constructivism and Meaningful Learning Theory rely heavily on students' prior knowledge (*16*). It is thought that if we, as instructors, are able to get into the minds of our students and ascertain what they already know, we can begin to build new knowledge off of that. Realistically, this is not an attainable task for an instructor in such a large class. If a student begins with a PTE that has two critical skills turned on and they obtain an incorrect answer, our system will ideally be able to determine why. If the submitted answer indicates that the student did not balance the chemical equation, the student will return to a level in which they learn to balance chemical equations. Once the student proves that they understand that critical skill, they may return to a problem similar to the original one to solve again. If it is determined that the student is missing the very basics of a percent yield problem, they may be given a problem without any critical skills turned on to practice first. Typically, the system begins at an average level. If the student quickly masters a topic at that difficulty, then they will advance quicker. Those who struggle more will be given additional problems to solve and may need to take a few steps back before being able to move forward. In this way, students who are well-prepared will master a learning objective quicker, while students who require more help are able to receive it. Students do not waste time on problems they can already solve, and instead spend more time on problems that they need help with. Two students approach the same learning objective from unique paths suited for their individual needs. Other programs report to offer similar adaptive capabilities, and we felt that this aspect was essential. Our program takes this adaptability one step further by using the individual student's pathways to make important decisions for the student, particularly concerning their role in the ASN. The remainder of this chapter will begin to address how these factors and the program's decisions culminate into important connections that link students based on these unique pathways. To the best of our knowledge, other online homework programs do not offer these capabilities.

Difficulty and Mastery

As mentioned, critical skills serve dual purposes. While the first was meant to help the student, the second allows us to assess a student's progress. Using these critical skills, we are able to test a given learning objective at different difficulty levels. Each question posed to a student is associated with a specific level of difficulty, and this level is a function of several components. For one, some topics or subtopics are inherently more difficult than others. Secondly, any given PTE can adjust its difficulty level by tuning the critical skills associated with it. As additional critical skills are added, the difficulty level of the problem increases. These factors go on to affect a student's "Mastery Level," a measure of how well a student knows a given learning objective, subtopic, or topic. Mastery is also dependent upon the expectations of the student. A student in an Honors-level General Chemistry course at a university is held to a higher standard than a high school student. Figure 2 illustrates this hierarchy.

We have established an algorithm that will take all of these factors into account and simply inform students (and their instructors) when they have mastered a given area. In order for a student to master the learning objective, they must prove that they can complete the problem regardless of the way it is asked and of which critical skills are turned on. In order to maintain a mastery status, however, students will be consistently re-tested on the concepts that they have already completed in order to ensure proper retention. Failure successfully to complete the old material will result in a student's loss of mastery status and the program will direct them to additional practice. If the student consistently and successfully retains the information, the system may re-test this material less often as time goes on.

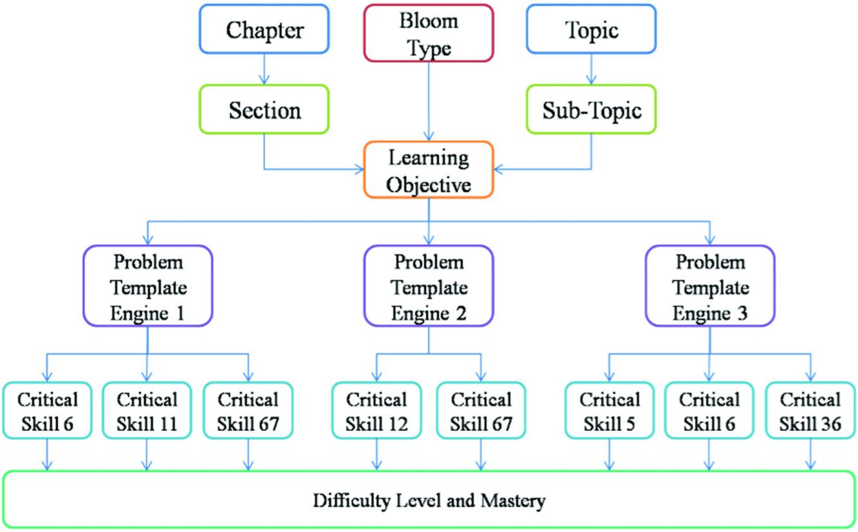

Figure 2. The hierarchy of desired content knowledge centers around a learning objective, tested by the problem template engines and tunable critical skills, which ultimately measure a student's mastery of the content.

Data Collection

In addition to providing the guidance students may require, such that they become more aware of their strengths and weaknesses, this online homework system produces an enormous amount of data. From general information like masteries to minute details like attempts on a single PTE, this data can be collected to help us understand more about the learning process and how to help those in need. Because the system is tracking the students, they receive immediate feedback about their progress. They are able to assess their standing in a more specific way, rather than as a simple percentage or letter grade. Our basis for these methods are Vygotsky's theory of zones of proximal development, and the related idea of scaffolding. Successful scaffolding has been shown not only to help students obtain the content knowledge, but also to build on their cognition and metacognition skills and encourage self-regulated learning, particularly for lower-achieving students (*17–19*). It is our hope that students not only use this information to solve homework problems, but also when making choices about independent studying.

Instructors can analyze the data broadly or at a fine grain, and may be able to provide appropriate intervention when needed. This includes an email system that is customized to fit each student. For example, a single message can be written to address multiple issues. If a professor wants to single out students who have been procrastinating, they can write a general message sent to all those who begin their homework past a certain date. If they wish to target students struggling with a particular concept and recommend additional practice problems or another resource, they can. All messages can be combined in a single email, with each part only showing up for those students that it applies to. Thus, students who procrastinate *and* are struggling with acid-base equilibria will receive one version of the email, while students who are only having issues with acid-base equilibria will not receive the first part. In the time it takes to write one email, instructors may send out emails to the entire class that are customized to fit each of their personal situations.

Virtual Classroom Environment

Addressing the Need

As technology improves and enrollments grow, we have seen more and more use of the virtual space in classrooms (*20*, *21*). Our university was of course no exception to the enrollment trend, and establishing a VCE seemed like a logical next step in order to provide students with additional academic support. Students are comfortable working in the virtual space, so it only made sense to meet them where they already are. We wanted to offer students the ability to form study groups, either on their own or under the facilitation of an instructor, which they could attend from the comfort of their own home and at a time convenient to them. All we needed was a platform suitable to communicating and working out chemistry problems. Equipped with a talented team of programmers and the support of the department, we made the push towards establishing our own system of VCEs.

Implementation

To start, it was of utmost importance that the system be user-friendly to both the students as well as the instructors. Most of the instructors, if not all of them, had previously only held physical, in-person class sessions. Learning to interact with students in a virtual setting after being conditioned to traditional teaching comes with a bit of a learning curve. To complicate this by using a clumsy, intricate system would surely be one way to lose the faculty's support. Instead, we focused on finding a system that would best mimic an actual classroom, with straight-forward tools and commands.

With a similar mindset for the students' side, we needed to ensure that there was first and foremost, no loss of learning. We considered all of the necessary operations of a smoothly-running classroom, and brainstormed ways in which we could implement these same components in a virtual setting. While we anticipated that the students would be relatively tech-savvy, we also knew that we could not make this assumption for all students. Not only did the system have to be straight-forward to use for the instructors, but the students had to learn how to use the system as well. Coupling this with the wide variety of possible laptop/computer settings, operating systems, and browsers, it was clear that the system also needed to be accommodating. In the end, the decision was made to create our own, in-house web-based application for the job. Students would need to have a steady internet connection and create their own account; however, they would not need to install any software or purchase extra equipment, aside from a few routine computer updates and a particular (free) internet browser. By creating our own system, it provided the flexibility needed to customize the settings to suit the needs of our classroom.

For a functional VCE, there were a few basics that we needed – namely a space to work out problems and a means of communication. We created a virtual white board that would allow the students or the instructor to write on just as they would on a normal chalk board or piece of paper, while others could watch in real-time. We offered a variety of pens and highlighters, as well as the ability to insert text and create or delete additional white boards. In a study group, students could have their own private whiteboard to work out problems, as well as a public board that everyone could see. Students can hear one another speaking through a microphone, and have the ability to see others via a webcam if they choose to. In this way, students can see and hear one another while simultaneously watching the white board, just as in real life. This lends a personal touch to the system that can easily be lost in a virtual space. If students wish to type to one another instead, we created a chatbox that allows them to do so.

Once we took care of the basics, our aim was to facilitate group work as much as possible. By creating an interface with GCeLS, students could import problems on any topic into their study group. Rather than having to search for a problem and type it out, this could be done quickly and easily. Likewise, because of the way the system is designed, each problem generated was unique. A group could now work together to solve novel problems.

Chemistry Interactive Problem-Solving Sessions (ChIPS) – An Alternative to Recitations

Like most large universities, Rutgers General Chemistry is divided up between two semesters. Although most students take the first semester in the fall and second semester in the spring, a few hundred students do end up enrolling in the “off-sequence” courses each semester for a variety of reasons. This totals around 2,000 students taking General Chemistry at a time. In years past, General Chemistry students had to register for a specific lecture time, which was linked to a particular recitation slot. The large numbers, combined with the inflexibility of registration and limited space often led to overcrowded recitations, delayed registration, and the turning away of students from the course. Those turned away were forced either to take the class during the summer, a costly option for many, or fall behind in their program’s curriculum. It was clear to the faculty that a change had to be made, but how to go about implementing any type of reform was not so evident. The solution had to be flexible, while still providing sufficient academic support for the course. At the same time, we had just begun to use the VCEs that we developed. Perhaps this was perfect timing!

In the fall semester of 2013, we launched our Chemistry Interactive Problem-solving Sessions (ChIPS) in lieu of our previous, traditional recitations. At the core, the operations of our VCE did not change much to accommodate these new recitations. Instructors still had a white board, equipped with the same writing tools. The main difference, however, is that the students could not write on the white board. Being that there was virtually no limit to the amount of students who could attend, giving them the ability to also write alongside the instructor would be, at best, distracting. Instead, the instructor runs the show. It is his or her face that is recorded while speaking, and the students watch and listen. Students could still type their questions or comments into a chatbox, or record their voice to be played at the instructor's discretion. Because the system had already been interfaced with eLearning, it was simple to give students quizzes at the end of each session. GCeLS could randomly generate a unique quiz for each student, based on the material discussed during class.

The boundaries for recitation do not stop with the basic VCE features, however. While students are seemingly watching the white board while the professor speaks, what they are actually seeing is the instructor's screen. If the instructor decides to step out of the recitation's web browser, the students will see this as well. Instructors took advantage of this by showing students videos of chemical reactions or molecular modeling simulations. Taking this a step further, we implemented the Glass Pane feature, which allows the instructors to actually annotate any web page, image, video, or document that they pull up on the screen, using a pen tool. Essentially, a virtual glass pane is placed over the screen and can be written on – a useful feature that cannot be found in a traditional classroom. Not only could instructors pull up other web pages, but they could write directly on top of the web page to edit or highlight something important with ease. To the best of our knowledge, this could not be done with other live-streaming applications. This eliminated the need for additional equipment, such as a projector or tablet, and could be done directly on an instructor's laptop.

As the first semester progressed, the technology team welcomed feedback and quickly implemented updates to improve the quality of the recitations. For example, instructors wanted to be able to use PowerPoint slides during their recitations. This is useful for showing diagrams and reference tables, pulling up lecture slides, or even just importing pre-made practice problems. Instructors can still approach their recitations in their own way, and many of them prefer to prepare material ahead of time to pull up. This feature allows them to do so, to the extent that they wish. Next, the team made some improvements to the chatbox. Useless words and phrases, such as greetings or unrelated chatter, are filtered out. This ensures that the important text, such as a question for the professor, is not pushed to the bottom of the queue. A polling feature was implemented to allow instructors to ask for a "quick show of hands," when asking questions. Students could select their option and the results are shown immediately on the screen. Feedback was not limited to instructor needs, however. As a request from students, the actual white boards from recitations were able to be saved and uploaded as images on the course website. This way, students no longer need to rush to copy notes. Instead, they could focus on watching and listening to the instructor, while referring to the notes at a later time. Each of these changes, along with some other minor developments, arose simply through feedback from users on both ends. Our technology team was not only receptive to these changes, but they were able to implement any requests very quickly.

Benefits of the Virtual Classroom Environment

Even after the first semester, both the students and the instructors began to see the benefits of the online structure of recitations. Students are able to pick any recitation they wish to go to on a weekly basis, often determined by their schedule. They are not attached to a designated recitation and thus the issues surrounding scheduling and make-up classes have virtually been eliminated. Students can attend multiple recitations each week, and they are allowed to retake quizzes for an improved score. This is a feature only made possible by the instant feedback that they receive. In the past, students would wait at least a week to receive their quiz scores back. In a fast-paced course like General Chemistry, one week can be much too late to seek help, as topics change quickly and build upon one another. We have found from our own experiences that some students will attend multiple recitations, even if their original quiz scores were satisfactory, leading us to believe they were intrinsically motivated to do so. Some students have a preference for certain instructors, and they, too, benefit from being able to choose their recitations each week. The students are able to attend these recitations from the comfort of their homes, dorms, or anywhere else with an internet connection. For the commuters, this can come in handy, particularly during inclement weather.

On the flip side, instructors also had positive comments for our team. The chatbox does not disclose a student's name, offering some anonymity. Instructors have often commented about the increase in participation, and we believe it is because students feel more comfortable speaking when others cannot see or identify them. It has been shown on occasion that there are gender gaps in traditional classroom participation, with female students participating less and being treated differently by instructors compared to their male counterparts (*20*). Online learning may be a way to close such a gap. Instructors no longer have to create or grade quizzes each week, as they are automatically generated and graded, which allots them more time to devote to preparing their recitations. During this preparation, the options are endless and more easily facilitated compared to a regular classroom. Instructors can pull up lecture slides, write on a white board, go to a video demonstration, and open up practice problems in a matter of seconds. There is no pause between writing on a white board, setting up a projector, and going back and forth between the slides and board, as there is in a traditional classroom. Coupled with the higher levels of interaction, instructors have a better flow in their classroom and the learning process is more continuous.

The Big Picture – Tying It All Together

The Critical Skills Network

We have already defined critical skills and their main purposes in aiding student learning. They help connect previously-mastered concepts to newer ideas, such that students are able to get a feel for the "big picture." However, the critical skills themselves can be connected to one another, creating the Critical Skills Network (CSN). Figure 3 gives an example of one such network. Within the CSN, a single critical skill may be connected to only one other critical skill, as a result of a hierarchy, or it may combine with one or more other critical skills to produce additional ones. Such a network comes into play when determining a student's mastery and future goals. However, the CSN also plays a crucial role in helping us to understand how to connect our students to one another, creating a meaningful network of student-student interactions.

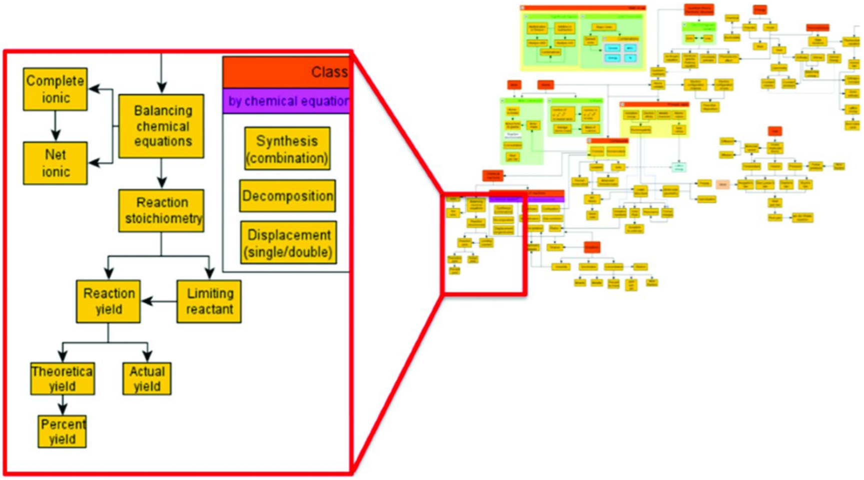

Figure 3. A small section of the critical skills network demonstrates how individual critical skills connect with one another or build further.

The Academic Social Network – The Incentive

In the Rutgers Chemistry Department, we run a teaching internship program for General and Organic Chemistry. This program is based off of the peer leadership model, in which former students facilitate learning with current students.While unique to Rutgers, it does share similarities with the Peer-Led Team Learning model, as well as other models founded on peer mentorship (*22*). From our own experience with the teaching interns (TIs), we have seen the positive effects on both the students and the interns themselves. The interns have reported that they receive great enjoyment out of helping others, and the students ideally have someone more "on their level" to help explain the material. In addition to the TI program, we run a popular group on a social media website that allows students in the course to communicate with each other. They often ask questions and other members will reply with help. While the site sees a great deal of traffic each day, it became clear that perhaps it is not ideal for working with chemistry problems. Students are limited to "abc" text, they cannot write equations or draw molecules, and often times, the communication is asynchronous. Likewise, the group is limited to only students in this specific course. These obstacles prompted us to wonder if there was a way to combine the social aspects of the online site with technology and data in order to create what we termed an academic social network (ASN).

The social incentives for the network already exist for many of these students. They enjoy helping one another solve problems, and they spend some portion of their day on social media websites (some students spend more time than others!). Meeting them in their own world, where they are already comfortable, seems like a logical fit. Likewise, between the quizzes given during recitation and the online homework system, we had access to potentially an incredible amount of data. What if this data could be used to link students together? How well a student performs on a given topic or even a given learning objective becomes a part of their individual profile. The time of day that they work on their homework becomes a part of their individual profile. Their level of study, location in the world, etc., could all potentially become a part of an individual's profile. Implementing a peer rating system as to how helpful they have been in the past can also shape their profile. This way, whether a student is stuck on a titration problem at 10:00 AM on a Monday morning or an electrochemistry problem at 3:00 AM on a Wednesday morning, they can be linked to someone who can help them.

The next step would be to provide students with a platform that is more suitable to the context of academia and solving problems that require text, images, and mathematical equations. What better than using our own VCE as the foundation for the ASN? Students can form study groups on their own, or join other study groups in progress. All communication is synchronous, which may be appealing to those who are experiencing some frustration with a problem or concept that they cannot get past. This is in stark contrast to forums, in which students post a question and wait for someone (who may not be knowledgeable or helpful) to answer. Currently, most online discussion takes place in the form of asynchronous communication (*23–25*). While this has been proven to provide various benefits when used as a course enhancement, including creating a sense of community, we believe the synchronous route will be more efficient and lessen the sense of "distance" in distance learning. Some studies have focused on the employment of synchronous learning, and while successes are evident, common issues are the need for additional equipment, the loss of personability, and inflexibility of use (*26*, *27*). These issues are alleviated with our system, as everything is run as an online web application, eliminating the need for software, students can see each other if they choose to, and students have the ability to type, speak, or draw on whiteboards in order to maximize flexibility in communication.

Figure 4 summarizes the various components that feed into the ASN. The ASN is an invaluable tool for connecting students to one another. Our eLearning system provides the content knowledge and ability to measure a student's success and areas of improvement based on a network of critical skills. The virtual classroom environment currently in place allows students to communicate with one another, or an instructor, in an environment that they feel comfortable in, with tools necessary to facilitate learning chemistry. As far as social networking goes, students are already active in that field on their own, providing all the incentive needed. The ASN connects all three of these elements and has the potential to revolutionize the way we conduct online learning and collaboration in the classroom. But the possibilities stretch farther than that. Professors have the ability to give massive review sessions that can both be synchronous, with live students in attendance, as well as recorded for those who could not join to watch later. Massive Open Online Courses (MOOCs) have gained traction lately for offering free education to anyone in the world with an internet connection. Students enrolled in one of these courses can use the VCEs to attend learning sessions, and then turn to the ASN for additional classroom support from their peers.

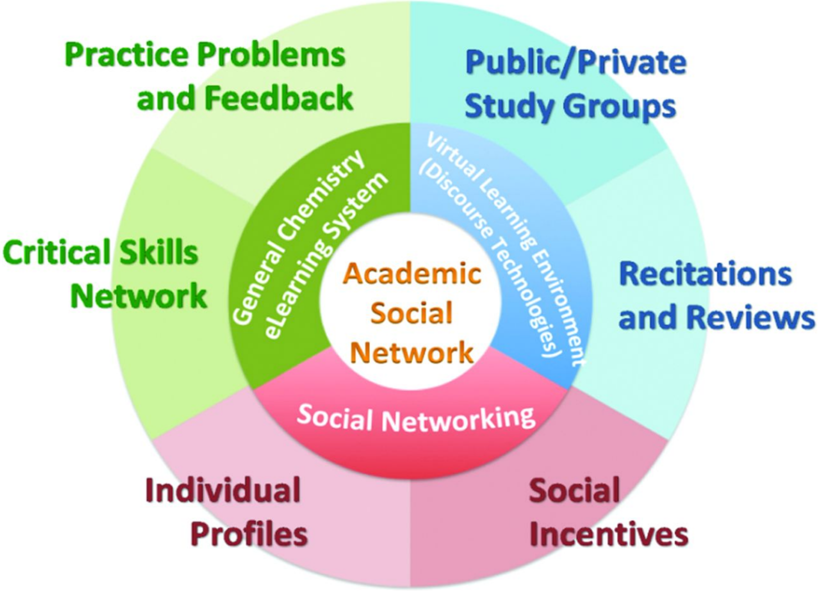

Figure 4. The various components of the Academic Social Network.

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