Justin 0:00

Welcome, everyone. This is our third and final webinar in our series on chemical misconceptions. Today's session is going to be hosted by Dr. Ryan Stowe, who I'm going to introduce in just a minute. Let me just introduce myself first. For those of you I have not met before, my name is Justin Weinberg. I'm one of the founders and CEO of Chem 101. And as a chemical engineer and a former chemical educator, I'm just so excited and grateful to have Dr. Stowe share his experience and expertise and insights with us today. As I've said on the previous two sessions, it's long been our mission as a company just to support chemical educators and the work that you all are doing to help students understand and appreciate chemistry. And I know we have many repeat attendees for the first two sessions but just in case, we're inviting some new folks, I just want to tell you a little bit about our speaker, as well as the overall webinar series. I again like to give a big thank you to Dina Borysenko, who is a faculty member over at Milwaukee Area Technical College, who has developed these three very informative events and new series for us. And if you have missed the first two events, you can always access the recordings and one of my colleagues will post a link in the chat for you all to do that. Now since pretty much all of you I think if if not very, mostly all of you are chemistry instructors or faculty, you've probably noticed certain common pain points that students tend to experience when going through a chemistry course. I know this is personally what drove me to originally create Chem 101 back in 2016. And over the years, my team and I have developed tools to help students master skills like dimensional analysis and drawing Lewis structures, practicing nomenclature, chemical equations and much more. But sometimes the misconceptions that we identify are actually partial understandings or misinterpretations of our own questions and to help us better understand how chemistry educators and chemical educators go through beyond the simple right and wrong diagnosis, we're gonna turn to Dr. Ryan Stowe today. So I want to introduce Ryan. Ryan is an assistant professor of chemistry at the University of Wisconsin Madison. He leads a research group that focuses on the ways chemistry learning environments can engage students and making sense of atomic and molecular behavior. Some of his ongoing projects range from small scale investigations focused on modeling student cognition, to very large scale cross sectional studies comparing transformed chemistry enactments that actually enrolled 1000s of students. Dr. Stowe earned his PhD originally from the Scripps Research Institute, he then joined Michigan State University as a researcher where he was mentored by Professor Melanie Cooper, which I think many of us know and worked on several projects related to teaching and learning and chemistry. I'll just tell you about three of them here. Number one, he conducted studies on student use of knowledge in the context of organic chemistry coursework. He led a team of teachers and researchers and designing and assessing curricular materials, high school chemistry curriculum, and third, he served on an interdisciplinary team that transformed the introductory science courses at Michigan State University by incorporating best practices and teaching. Ryan has a really interactive presentation for us. We're going to be making use of Zoom’s chat and pulling in q&a. Um, the title of the talk he's going to be giving us “an alternative to misconceptions view of learning and assessment.” And before I hand it over to him, I just want to remind everyone that we are running a chat, which you are all free to post in. We will be posting some links in there. So make sure to pay attention to that. But if you have any questions or thoughts or comments or things that you'd like Dr. Stowe to hear today, we would love to hear from you. So make sure to put your thoughts in the chat. When you do that just make sure you set your to field to everyone or all panelists and attendees so everyone can hear what you're saying. Not just us, because I'm sure other folks will be thinking the same thing as you. So with that being said, I'm going to hand it over to Ryan and stop my screen share. Ryan, we're looking forward to your presentation.

Dr. Stowe 4:27
Thank you for the kind introduction Justin. And just a special thanks to Dina for orchestrating this series. It's really an honor to be part of this discussion. And thanks to everybody who is here. This is a crazy time for the semester, I'm sure for many of us. It's the end of the semester. We're all maybe orchestrating final midterms or final exam. And so it means a lot that you took time out of your I'm sure extraordinarily busy schedule to be part of this conversation. I suppose I should ask can you see my slides. This is the traditional zoom greeting and this world we live in now.

Justin 5:02
You're showing up just fine.

Dr. Stowe 5:06
Excellent, thanks. Okay, so we're gonna think together today about what we really can infer from what students write in response to open ended tasks. So I guess the question is, you know, what do we mean by misconception and what sort of inferences can we make from answers that might not be totally correct, that students produce on on quizzes or exams or on homework? So before we get started with the main discussion, I want to really acknowledge my group. I'm going to be presenting some data from a couple of projects that are ongoing and these are the folks who did the work. In particular, Kara Schwartz, who's in the middle on the top row, analyzed the student responses that we're going to be talking about. Vanessa Ralph, who's on the left on the top row, did some quantitative analyses that I'm not going to discuss but also relate to this project. And I'm really enormously fortunate to work with such a wonderful group of colleagues in my research group studying, chemistry learning and learning environments. So I want to start with acknowledgments because I think that's a good order of operations. I bet you didn't think you're going to have a George W. Bush quote at the beginning of a talk. So there you go. You're welcome. He did say this. I found the video. It's a... it's a fun time. It's actually a pretty good question, though. Even if it's not worded all that well. Like are people learning what we care about? How do we know? What sort of assumptions are underpinning the inferences that we make from students write and say and are those reasonable assumptions? So I'm gonna reword it a little. How do we know that students are progressing towards the sorts of goals that we as chemistry instructors really value? And I want to start unpacking this by defining a space that I would argue is what we, what we ought to value. Oops, I skipped a slide. I would argue the core of chemistry as a discipline is connecting molecular behavior to how and why things happen. The power of molecular level ways of thinking is that they let us explain things in the world that cannot be explained in any other way. And they let us design solutions to important problems, whether these are small molecule inhibitors of disease relevant macromolecules, whether these are our polymers that are especially rigid or conductive or

whatever, something that is useful and meets a need. Chemistry can help us address these challenges, which have implications in human health and climate change and a host of other massive problems that society is facing. At the core of all this, is this process of connecting molecules to how and why things happen. And so we want students to do the same sort of thing. Something potentially heretical is that skills devoid of connection to phenomena are actually not that important. So just drawing a Lewis structure for no reason is not something accountants does and not inherently very valuable, but you can construct Lewis structures in order to predict or explain for example, boiling point differentials and that can have value in meaning. So our phenomenon for today that we will be focusing our discussion on is taking lithium chloride, which I'm told this is by a two second Google search, and adding it to water and noting that the beaker warms. And certainly I'm sure all of us on this call are immediately thinking oh, well okay so your ionic lattice is, is added to the solution. And so we see formation of attractive interactions between solvent and solute and these attractive interactions act to help pull away ions from the ionic lattice we know that as interactions are formed, energy is being released as interactions are broken energy is required. And so we probably have something like a mechanistic movie running in our mind about how all this happens. But this is actually deeply non trivial for students to explain. And in fact, when we look through the literature on student understandings of the process of dissolution of ionic solids, endothermic and exothermic, basically, all we found were collections of student difficulties. That can be useful, but certainly isn't a useful endpoint. What we want to know is how can we create learning environments to effectively support the sort of sense making we care about.

Dr. Stowe 9:16
So simply saying we want students to explain how and why phenomena happen is pretty vague. And so we need to be explicit about what we want students to know and be able to do if we have any hope of assessing these sorts of performances. The National Academies did this for K through 12, Science Education with a framework for K through 12, science education, as well as the corresponding next gen science standards. But there's nothing analogous like this in chemistry of present, at least not from something like the National Academies. So instructors can create performance expectations such as this, which blend what we want students to do with their knowledge, that is, simplify what's going on in a system in order for you to predict or explain or developing and using models, what sort of fundamental ideas we want students to represent and incorporate into their model. So here we have energy and electrostatic interactions, and how we want students to frame the phenomenon. What aspects of a very complex occurrence we want students to direct their attention toward understanding? Once we have an explicit expression of what we want students to know and be able to do, we can think about what sort of evidence we would accept that students could engage in the sorts of performances that we defined. Typically when one does this one either implicitly or explicitly comes up with evidence statements are things that students could draw or write that would indicate an understanding of the process of dissolution in the energetics that govern it if we're thinking about the past performance expectation. When you have an idea of the sort of evidence that would convince you of what students, students knew and could do relate it to the relevant performance expectation, then you design the task and this is a well known process of evidence centered design of assessments. It's been around for quite a while. So the task that we are

going to use today we're going to examine student responses to is given on this slide. It's got three parts. It was developed by Oscar Judd who was a graduate student in Melanie Cooper's group, and it relates to our focal phenomenon so lithium chloride dissolving in water. So first, students are asked to represent the process of dissolution at the molecular level as lithium chloride is added to water. There are snapshots of undissolved, dissolving and dissolved. Second, students are asked to describe what they drew. So what is the process that undergirds lithium chloride dissolving in water and how do you express that in words? And then finally, number three, is where the rubber meets the road. How can this molecular level mechanistic understanding you have of the process of dissolution be connected to this thing that you observe? You can add lithium chloride to a beaker of water and you will see that it warms. How can you connect that warming to the interactions between solute and solvent particles? So there's something that till now we haven't really talked about and I want it to be explicit, regarding in just a moment, why am I happy to provide slides? If you, if you email me, that's not a problem. So we've talked about observations, right? The things that students write and a response to an assessment task. We've alluded a bit although perhaps not explicitly discussed how we would interpret those sorts of observations. So what would we infer based on what students wrote or drew depending on whether we're talking about a second part of the assessment or the first part or the third part? The sorts of inferences that we think are reasonable and the sorts of observations that we think have the potential to elicit valuable evidence are informed by how we think about learning. That's cognition. It's how we model learning. This is not super intuitive, and I'm going to spend a good chunk of this time trying to convince you that how we model learning is really important to our work as instructors. So there's a continuum of ways that people talk about how understanding can be expressed, and I'm going to really stake out two parts of this continuum. There's a lot of stuff in the middle that I'm not going to talk about. On one end is the perspective that students have more or less stable theory-like understandings, and they draw on those in a more or less consistent way across contexts to answer the sorts of problems that we give in general or organic or physical chemistry. If they recognize some sort of inadequacy in this theory. Strike and Posner proposed in the early 80s, that there will be dissatisfaction with their current theory-like understanding and if a different theory, one that addresses their dissatisfaction is proposed, there can be a process of rational conceptual change where the wrong central concept is more or less swapped out for the right one. This is the most simplistic sort of misconceptions model where we're assuming for example, that a wrong answer means some sort of coherent and stable wrong idea, and that we need to show students why their idea is wrong and give them the right idea and then they'll just swap them over. And now they will use the right idea and all sorts of different contexts.

Dr Stowe 14:13
So I want you to assume that for a moment. Assume this idea that student responses indicate them drawing on a coherent and stable theory like framework, either a correct conception or a misconception. Here's part one of our prompt. I'm now going to show you a response to part one of our prompt and ask that we fire up question one of the poll. So from this response, and hopefully you could still see it. What do you infer about student learning? If you're assuming this conception style view, that a student response indicates a coherent and stable theory like construct of exception or a misconception. I am not allowed to give up and that is okay. Let me

give us a minute. So you get this on a quiz or a test or something formative, like homework assignment.

Dr. Stowe 15:37
Always better with like live humans and I can tell when people like done voting and sort of looking around, but I can't tell them that now. So let's let's close the poll because I'm too impatient to actually wait for a minute. And can we see the results? I don't have them up. Okay, so we have a distribution of responses here. So what we see are big circles and little circles and these appear to be busting up. If we assume that this represents some sort of coherent, stable understanding that students will always use consistently in all contexts all the time... then I think it would be reasonable to say something like C for example, or even something like A... that, that, you know, maybe students aren't thinking about solvent. Maybe students think that just the solutes just bust apart, and that the solvent doesn't really matter. B we're gonna get back to, I like B a lot. B is my favorite response to these three. But B talks about context and it implies a context dependence to student thinking. It is different from the sort of coherent theory-like understanding that was advanced in a lot of the misconceptions literature. So let's look at another one. So now this is part two. So students are asked to describe what happens as lithium chloride dissolves in water. Here's a response. I'll give you a moment to read it over. And then I'll... I guess we could put the poll u now since the poll is actually where the answer responses are in, that way, I won't fade out the Text Block. Thank you Dvora, if you're running this. Thank you for, Justin, whoever's running this I appreciate it. Okay, maybe about 15 more seconds and then we'll close the poll. So I'm not looking at the chat. So Judith Ledge, if you, if you think none of the above, which are you sort of least opposed to I suppose? I put in firm instead of anything more conclusive because of course, this is one response to one assessment so the conclusions are not terribly strong. It's this kind of a ‘What direction are you leaning?’ sort of question. All right. Let's close the poll, please. Let's display these here. Alright, so here we see a nice articulation of the role of solvents. So we see formation of attractive interactions between solvent and solute particles. And so clearly this student is, is thinking about solvents role in the process of dissolution in what they're writing. I think if we, if we take the view if we have on our theory theory hat, and we take the view that responses represent some sort of coherent, stable conception or misconception, than it seems… oh, so... we... did we redo number one, this is poll two, sorry, I had a moment of confusion. Then we could say that students understand solvent for example, maybe we assume some sort of durable understanding of the role of solvents in dissolution. A, like B on the last poll, talks about context in the moment, in the moment, drawing on particular ideas and connecting them and I would argue that's not typically how the sort of 1980s era conception and misconception literature claimed that responses came about so they didn't talk about in the moment stringing together of ideas. They talked about drawing on theory like structures in the minds of students. But A is my favorite answer to this as well.

Dr. Stowe 20:06
So these are from the same student. So recall, if we go back a couple... no solvent at all… it all just looks like, like circles falling apart and so many folks, I think rightfully, if assuming a theory theory perspective on the students understand or don't understand, assume that maybe

students don't understand how solvent affects the solution or don't think solvent is important. Here of course, we have a pretty explicit articulation of part of solvents role in the dissolution process. And so the fact that these are both from the same student indicates that this student but different ideas are important to represent or to put into words depending on which part of the problem they were engaged with. So this suggests not that students have this coherent and stable conception or misconception that they draw on the same way in all contexts, but rather, we're talking about something a bit more dynamic. So here's the question, two misconceptions as talked about, still by some in the community, but certainly in the 80s a lot more than than now. The students possess coherent and stable, wrong theories about how and why chemical phenomena can happen. And how do we know? Well, so there's some literature that would indicate the answer to that question is not usually. So here, this is a study from 2013 from Melanie Cooper's group. It was published in the Journal of Research on science teaching. If you're... if you'd like it, I'm happy to send it to you, if you send me an email. I realize it's behind a paywall. I'm sorry for that. I have a collection of open source resources at the end of the talk. But they sat down a student or rather collection of students, and they presented them with three pairs of substances. And these differed in different ways. So in this first pair, you have ethanol and ethane. So one an alcohol, one an alkane. In the second pair, you've got a methanol and ethanol, so a smaller and bigger alcohol. And then finally, in the third pair, you have substances that have the same molar mass molecular formula, but of course differ in terms of conductivities, you have ethanol and dimethyl ether. Students were asked to pick the compound with the highest boiling point and explain why. And I think it's fair to say that Melanie and Leon who is the second author on this, were somewhat surprised by what they found. And what they found that was that, depending on the pair students were asked to consider, the ideas that they called on differed dramatically. So as students either correctly or incorrectly picked one of a particular pair to have the higher boiling point and had some sort of reasoning. The reasoning they employed for the second pair or the third pair was often wildly different. So for this first one, there could be some difference it could either say the bigger one has the higher boiling point. You could say something about the oxygen. You could say something about hydrogen bonding, if you remember that buzzword. At the bottom of this slide is a series of resources on this sort of conceptual ecology view of learning if you're interested. Just thought I would call those out. Here also the idea that the bigger one has the higher boiling point will help you out but many students expressed idiosyncratic ideas when transitioning from the second pair or from the first pair to the second pair. Now that you can't any longer say the heavier one has the higher boiling point because they have the same molar mass, different ideas were often introduced by many of those who were interviewed. So one idea that kept popping up was that symmetry has some sort of role. The take home of that work, is that it appeared that student cognition elicited by these assessment prompts and certainly interviews are also a way of assessing, varied depending on context. So students were not drawing on the same right idea or wrong idea in the same way every single time a slightly different problem was put before them. Instead their thinking was really quite dynamic. So let's go back to our problem. And I suspect the answer many of you wanted to pick for the first set is not going to be the answer that I think is very consistent with the resources view of of learning in the second step. So here we have lithium chloride represented now positive and negative, and then some squiggles. If you assume a conceptual ecology view that students are drawing on and connecting the ideas they think will get them where they need to go in the moment what would you infer?

Dr. Stowe 25:09
So in response to Jay's comment, I wonder upon follow up questions, if there would be parts of students reasoning that are potentially productive, but maybe just not connected in quite the right way. They aren't. So okay. I'll... so answer the poll that's given here and we'll work we'll work with it.

Dr. Stowe 25:45
Alright, well, let's just close the poll and we'll talk about it. So here just as we saw with the first step, we did not see a tremendous representation of salt that we would align with as chemistry instructors, right, we see sort of squiggles. So I think from a conceptions perspective, one might infer that solvent doesn't matter here from this student's response. However, there certainly are productive ideas that the process of dissolution represent or requires these oppositely charged ions in the ionic lattice to separate. Exactly how that happens is left a bit vague here. This is a bit of a wall of text, but this is a response to the second part.

Dr. Stowe 26:48
And I'll put this up I feel free. I don't know if the poll aligns with this, cool, if not, you can just put your you know, ABC in the chat, that's okay. That'll work too.

Dr. Stowe 27:10
So again, this isn't us now assuming that there is a context dependence to the ideas that students call on and connect. And if you tweak the context a bit you might get a different collection of ideas of students calling and connect. Oh, okay, let's close this one. You see the slide. So you can just in the chat, right, A, B, or C. I don't know if the... I mean, is poll four consistent with the slide or no?

Dr. Stowe 27:51
Okay, all right. Not a problem. All right, stood the march of the A's. Cool. So clearly, this student is saying quite a few things about solvent and about electrostatic interactions between solvent and solute particles. And that's, that's great. When we say understands or misunderstands, I think we have to be careful that we're not implying in all contexts all the time, because we can't know that from one response in one context. So certainly in this context, students are productively connecting ideas about how solvents participate in the dissolution of ionic solids, for sure. So I think that's why a lot of folks resonated with A, I think C is also consistent with this idea of ideas related to electrostatics being activated in the context of the prompt. Just as before, so I guess I didn't have the slide this time. Just as before, these two responses are from the same student. So the same student who drew the squiggles and didn't use a sort of canonical representation of solvent molecules forming attractive interactions with positive and negative ions, add a pretty nice and elaborated solvent involved discussion of the process of dissolution in the second part. Okay, so this is two students... that doesn't tell you all that much. Let's take a look at more. So something that my group does pretty routinely, is we get these

massive data sets where we have like hundreds of students respond to a question like this. And we try to, in a meaningful way, describe the ideas that students saw fit to activate and connect when they responded to a particular prompt. So here we have depict the process of dissolution. So I undissolved, dissolving and dissolved. Students could take the interactions breaking and forming. So here we can see interactions broken in the lattice and they go from undissolved to dissolving. We see interactions forming between water and the cations and the ions with a very nice description.

Dr. Stowe 30:04
We can say, breaking or forming so either students are representing interactions breaking or interactions forming if they draw something like this. So this is kind of the lattice falling apart, interactions or breaking. You could also imagine one in which interactions are only forming, but we think that would involve just water clumping around the lattice. We didn't see that too often, this was more common. Students could also draw something that doesn't clearly indicate that they are meaning to represent interactions breaking or forming. This was really rare. And so we're not really totally sure what this means. But we got a few responses, like this, and that's represented by a third category. Now the second prompt, as we've talked about is students being asked to describe what they illustrated in the first prompt. And so we can use the same sort of descriptors to represent the ideas students are connecting in their written responses. as well. So I've tried to indicate both the salient parts here but student, the student in this response is indicating that they saw fit to talk about interactions breaking and forming during the process of dissolution. Ill put this up for a second, because I know it's a fair bit of text. It's in bold, the important bits. Students could also simply talk about interactions breaking or interactions forming and so here attaches we took to represent interactions forming. We are not overly hung up on buzzwords in my group, we try to acknowledge the substance of student thinking, not how well they've memorized a glossary. Turns out that isn't all that important. And then students could just not mention interactions at all in their, in their written response. And so here this is, is fine. Yeah. Exothermic dissolution means energy is transferred from the system to the surroundings, but interactions are not discussed. I should add that when we code responses in this manner when we describe the sorts of things that students write, as I'm discussing right here, we're not saying this one is correct, and this one is incorrect. We're describing the ideas that students often get to call on and connect in this moment. So let's take a look at how these two align and we can see they actually align pretty well. So about 166 of the 300 or so in the data set that I'm presenting here today, who drew interactions breaking and forming also described interactions breaking and forming, but not all. So certainly we see 36 that have an inconsistency and we saw some of those inconsistencies in the example responses that I provided. So this indicates for many students across at least two contexts, they did see fit to consistently both represent and describe interactions, breaking and forming. So this indicates for many, there might be some stability across context to what happens when a process dissolves. The third part is a little different. So in the third part, we're asking students to think about why a beaker warms when you dissolve lithium chloride in waters. We want students now to talk about the relative strength of interactions formed and broken. So students could talk about how the fact that the beaker warmed means that the interactions formed are stronger than those broken. We are hopeful this represents that formation of interactions releases energy,

breakage of interactions requires it. So this is certainly a response that we would be happy to see. They could say something that is a truism about the energetics of interactions breaking or forming, but not connected to the focal phenomena. So here yeah, if you form a hydrogen bonding interaction, energy is released. But this is not clearly connected to the beaker warming in terms of relative strength of interactions formed and broken. And then, neither either represents talking about energetics incorrectly, or simply not talking much about interactions at all. So here again, we don't really see mention of relative strength of interactions in the response. Clearly, there was at least for these students, at this point in time, a bit of a disconnect between being able to describe what happens and connect molecular level behavior to something that you could observe. Because of the 166 that were coherent, between parts one and two, only 49 also connected this thing that they described to what would be observed if you added lithium chloride to water. So only 49 of this population talked about the relative strength of interactions formed and broken. There's another animation there. With many of the others, either not invoking interactions at all are, or only saying some sort of truism about the energetics of interactions formed or broken. So let's step back from this particular assessment item. If we were only to ask for students to select some sort of truism, so lithium chloride is added to water. What word would describe the energetics of this process? And they pick exothermic, endothermic and some distractor. That doesn't give you very much information.

Dr. Stowe 35:15
They could have just remembered a buzzword, they could have assembled a heuristic that allows them to pick the right answer. But does it indicate a kind of mechanistic understanding of how molecules interact to give rise what’s observed. Something like this instrument provides a lot higher resolution so you have a drawing and then you have a description. And then you have a third part where you're asked to connect molecular activities to something observable. And so I'm going to tell you a bit more about assessments of the sort just a moment. But I would really, really strongly advocate to the extent that is possible in your local context, that you provide ample opportunities for students to construct explanations for how and why things happen and to represent those explanations across contexts. Because if you don't do that, these sorts of stabilities and instabilities will be hidden from you. You may assume that people understand things when maybe they don't. Or you may assume that students misunderstand things, when actually they just had one little part of the set of connected ideas that wasn't quite right, but they were most of the way there. So the take home messages thus far are that it shouldn't be assumed that one wrong answer at one point in time on a given question represents a stable wrong theory across all contexts. There's quite a bit of evidence to back up the statement at this point. I just presented a little bit here today. But you can suddenly tweak the wording of an assessment prompt and get dramatically different responses from students in many, many different contexts. And so you should only assume a durable understanding or misunderstanding if you see consistency across multiple contexts and the ideas students call to mind and connect.

Dr. Stowe 37:00
The second part relates to what I was just talking about. So if we really care about students connecting molecular behavior to how and why things happen, we need to give them lots of

opportunities to do that. And we need to respond to the connections and misconnections we see in their responses. This is a bit of a long item, but it's one of my favorites, so I pulled it up. This is such an item for organic chemistry and this is one that we gave in our second semester course about a year ago. A signature of these sorts of items is first there in the context of some sort of observable. There is a thing that happens that we want to understand. If you do not have a thing that happens that you want to understand, then there is possibly no real utility to the skill or the fact or whatever that's being assessed because anything chemists do is animated by a desire to understand some sort of observable. So here's the phenomenon: we can see that we have two different ways to make the same amide, one is way more harsh than the other. It takes a lot longer, you got to heat it more. Here we're actually asking students to construct a representation that lets them explain the focal observable. So students are asked to construct a potential energy surface where we want them to represent the relative reactive energies of system A, relative to system B. We want them to represent that the ester system is going to be lower in energy than the acid chloride system. And so the activation energy for the reaction shown in Part A is going to be much higher, it's going to be much slower. If they just draw a picture, we don't know why they do the picture. So part two is critical. Part two is kind of like Part C of our dissolution prompt. So students now are asked using the representation to explain why procedure A requires a higher temperature and longer duration than procedure B. And we really want explicit consideration of the energies of the two reactant systems and in particular, we want them to think about pi conjugation of the chlorine to the carbonyl pi system relative to the ethyl oxygen to the carbonyl system. This is an assessment that could broadly be considered a three dimensional assessment because students are expected to draw on fundamental disciplinary ideas to engage in the sort of work that scientists do. If students rarely or never encounter this sort of assessment, we haven't the foggiest idea whether they are inclined to engage in authentic disciplinary work. These sorts of assessments are really, really important. So there's a few papers and I'm happy to talk more, we'll have a few minutes to talk about 3d assessments or anything else you find interesting, but I wanted to put these resources up. Because the first of these is a way to take a look at your existing assessments and categorize the extent to which they have the potential to elicit evidence of students connecting fundamental ideas to how and why things happen. Both the dissolution assessment and the assessment I very briefly showed a moment ago have this potential. So students are asked to think about energy and electrostatic interactions and connect that to something they could observe.

Dr. Stowe 40:11
The second of the two has to do with strategies for adapting traditional tasks, so tasks that maybe don't have part two, or tasks that maybe are just draw a picture without an explanation. This paper provides strategies for taking those tasks and creating three dimensional tasks, or creating tasks where students are asked to connect fundamental ideas to causes for phenomenon. And finally, the third one is about spectroscopic argumentation. So this is student engagement in a particular practice. So taking evidence, analyzing and interpreting that evidence then making some sort of evidence based argument about reaction outcome. The reason I picked that one is because it, like the other two, is an open source article available from J. Chem and these are the two bottom ones for Editor's Choice and the top one is in Plos One which is always open. So happy to share links. I would highly recommend! I think the first two

are the most useful, but I put the third one because it gets a little more information to the organic chemists in the audience that you want to think about spectroscopy. And the third part is also pretty critical. So assessments messages to students what we care about. And so they're, yeah, they're valuable research and instructional tools. Yes, we ask students to connect ideas to how and why a phenomena happen across contexts, we can see the connections that they find intuitive and the connections that are maybe less intuitive, and we can build instruction to help support the last intuitive connections in a way that we couldn't do if all we did was ask multiple choice skill based questions. Also, they tell students what Chemistry is all about. So students who only ever do arithmetic problems, in for example, General Chemistry or only draw Newman projections in organic chemistry are going to get the message that chemistry is about doing decontextualized math problems and drawing pictures for no good reason. And so this is really problematic. Cool, so we have about 15 or so minutes. Let's have a conversation. I know that there's... Bernadette had a question which I'm happy to read or you can certainly welcome to unmute and ask it if that's the thing we can do.

Justin 42:16
Yeah, thanks, Ryan. I mean, this was extremely informative and very engaging. I'm sure everyone enjoyed it as much as I did. I'm actually gonna steal back screenshare real quick to just facilitate the q&a and just take care of a couple other things folks might be interested in. So we have a little time for q&a. So I do want to invite everyone to use the chat or use the raise hand function in zoom. So if you want to raise your hand, I'll be able to see that and we can start to get some live audio q&a going on. So folks want to take a minute or two to think about the questions for Ryan. We'll be able to address those directly here. While that's going on, I do want to remind everyone that this is being recorded and we will be sending out a link to the recording so for folks who have missed it or want to share with your colleagues, you'll be able to do that. For those of you who want any certificates of attendance for professional development reasons., please email us at learning@101edu.co. My colleagues will post that into the chat so that you can just send us a request for that and we can send you over a certificate. I also do want to invite everyone who's here to attend some other events that we are putting on later this month and then we'll turn back to Ryan for q&a. So just want to make everyone aware that we are putting on some mini sessions later this month starting actually next week going through the 16th. These are half hour mini sessions that we're running at 12 Eastern from 12 to 1230 each day, and they're on various topics that, you know, chemistry instructors are engaging in these days… activating students engagements, managing classes with diverse skills, background knowledge, and also making chemistry homework more of a learning experience. We also have another event coming up on the 17th, related to organic chemistry, which is specifically about technology we're developing for helping students understanding arrow drawing and electron pushing in reaction to reaction mechanisms mechanisms and resonance in organic that's happening on the 17th this month. I'm going to post the links to those events for those who are interested. But with that, I'm going to go turn this back to Ryan and check the hands for any live q&a that we want to do. So I know Bernadette has her hand up so I'm going to pass her mic.

Dr. Stowe 45:02

It's a great question. I'm excited to hear you say your question right now. This is a lovely question.

Bernadette 45:08
Hi. I have been sort of following Melanie Cooper's research a little bit, not recently, been too busy. But I I'm really intrigued when you have been posting and researching these responses to the students that in their lecture portion if they have been given any kind of foundation in order to build their depictions or do they just kind of do from scratch like maybe in in Melanie's classes, the process is to give them opportunities to build their foundation build their own understanding but in other courses other universities other you know, classes would these questions be appropriate for students who already have images already that they have been seeing in textbooks or instructors have presented to them. I'm just wondering at what point what path was most effective for the students to get there, if they're allowed to come to their understanding will be hoped to be you know, they're correct understanding that we all kind of, you know, go with or do we help them along, give them a booster and say okay, at least we're going to tell you at least this image about molecular behavior. And even the simple act of drawing a circle and put a symbol in that is not something that I think students intuitively would do. So I'm just wondering where we start in order to get to the point where they can project strong understanding about boiling point, the act of boiling itself. There's a lot of behavior that is really complex. So I'm, I'm wondering, you know how to get the students there most effectively, without being sidetracked by misconceptions.

Dr. Stowe 47:07
Thank you for that question. So the students in our data set are from three different institutions and they definitely approach engaging students and explaining dissolution in very different ways. Which is to say some actually have students explain dissolution and some really do not. In terms of representation, certainly students are drawing from what they've seen their instructor do or what they've been rewarded for doing on homework, in terms of what they choose to represent. So the idea students call to mind and connect when asked to engage with an assessment task, are those ideas they think will be successful. That they've seen be successful in context that they find similar. Those contexts are usually past assessments, things they've seen the instructor do things of that nature. In terms of where you start, I'm pretty aligned with a lot of the K through 12 people who would advocate that we should really start with a phenomenon. We should start with this is a thing happen, that we that happened that we don't really understand. And we need to first go down to the molecular level and consider how we represent that and think about how interactions between populations of molecules might cause this thing that we see and that requires to pretty carefully select your phenomenon. So this phenomenon that I showed of exothermic distillation of lithium chloride, really complicated. So in like Melanie's clue class, this is going to be something you do at the beginning of the second semester. This is not something you would give people like day two, because it's quite complex. But by starting with the phenomenon, and by grounding the representations explicitly and the need to explain things, there is purpose to what we represent. So you're not just drawing circles because drawing circles on a quiz a week ago, got your four points and so you think you should draw circles, because of course that's not something they're ever going to run into once they

leave school. So anyway, I think the purpose of why we draw the things that we draw needs to be foregrounded, to a greater extent in most chemistry classes. That does not mean that there's no direct instruction about reasonable representations. Students are probably not going to de novo come up with Lewis structures, they're certainly not de novo going to come up with quantum mechanics and orbital representations and think about orbital overlap. So there's certainly a place for some direct construction. But all that should be from a student's perspective linked to figuring out how and why things happen, otherwise it's purposeless. I mean if it's just we do this skill, then this skill then we learned some solubility rules and we move on with our lives like that doesn't matter. I don’t need to know solubility rules for no good reason. Does that help at all? Maybe?

Bernadette 49:48
I have a follow up with that. So I'm slightly familiar with modeling pedagogical approaches in high school. And I would love to, you know, follow that up because of students who have been exposed to that in the high school level. I know that I don't do that. You know, I have a lot more content to work through in a much shorter amount of time. So traditionally, you know, we in higher ed have bypassed that but I think it does the students a disservice if then we start to ask them about those conceptual ideas and they don't have any opportunities or any approaches that they've been exposed to. So, and I like the idea that absolutely I think what we should be connecting are those these abstract concepts about behavior to direct concrete applications, but right now, we are still in a very traditional pathway, at least in our institution because I'm at a community college because we have transfer agreements that we need to maintain which means that we are covering certain traditional topics and essentially in the traditional manner that they have been taught. So to turn around the big ship takes a lot of effort and I would love to be bringing this into to have the students continue to think about part particle behavior in this way, but I, I feel I'm kind of constrained with time and with who and how students can transfer these courses and to have the content, you know, covered effectively. So I'm wondering if I, to be honest, I wish the textbooks as I mean, I don't use a traditional textbook, we kind of have our own thing and we have Open Stacks and reference, and we have tools like Chem101 in order to help them with, you know, small skills, but I don't know. I think that the reliance on traditional format of textbooks, really doesn't allow us to broaden our approach to teaching chemistry in the way that you've described, which I would love to follow.

Dr. Stowe 52:08
Yeah, it's a fundamental rethink. So we're doing this in high school. And it's been, it's a multi year project with several full time researchers and it is not something one could just like I could not do this by myself as I was teaching, it wouldn't be feasible. So you, I hear you definitely want to acknowledge that those tensions are massive. Okay, I see some things in the q&a. Is that where I should look next, or

Justin 52:36
Yeah, we do have, we do have well, one person actually posted six questions within the q&a. And then so we have a question from David and then the series of questions from Bob Potter.

You all also have one other faculty with their hand raised in the in the attendees list, so maybe let's hop to them first. So that's Judith Herzfeld. So Judith can ask their question out loud.

Dr. Stowe 53:08
Sounds good.

Judith 53:10
Okay. I think I've unmuted if you can hear me. I just wanted to respond to that last point because the time constraint is enormous, but this is from my point of view an absolute prescription for the flipped classroom that you need a textbook that does what you want to be done in a basically one way fashion. Outside of the classroom and in the classroom, I love to use drawing exercises, concept tests, and with the drawing exercises, I have them do it at the end of class they hand them in with their name on the backside so it won't show because I'm going to show them to the whole class, the beginning of the next class. And we compare and contrast different drawings and figure out what was a strength or a weakness of different drawings and what might be a complete or best combination of them all. But you cannot do that if you're just straight out lecturing. You can only do that with pure instruction flipped classroom of some form. Otherwise, I think it's from my point of view, pretty hopeless.

Dr. Stowe 54:15
Yeah, and I think there, there also need to be other components of the learning environment systems that align with the sort of performance and so assessments are hugely important. So students need to be rewarded for reasonable connections and they need to have practice and making connections between molecular behavior and phenomena. And I think Bernadette was saying this too. If you've never seen these sorts of questions, that organic question I gave, if you're in a normal organic class, and you're just memorizing a whole bunch of reactions, and someone plops that question in front of you, you're going to justifiably freak out. Like, there needs to be substantial support and signposting that we now value explanations and models and that that can and should be what we do in that the class meetings and small group discussion meetings and the sorts of things that we emphasize for board on quizzes and exams. Absolutely.

Justin 55:09
Thank you, Judith. We did have another hand go up from Bob Potter, who did actually post some questions in the q&a section. So I'm going to give Bob a um… well his hand just went down. So I mean, he did still put some questions in the q&a section Ryan. So if you maybe want to address some of those I don't know.

Dr. Stowe 25:29
I can quickly address David's first because I think he was earlier and then I'll go, I'll talk because it just felt so... So David, there's actually been a lot of research and a lot of different contexts that this is just kind of how people tend to think. Cognition is a dynamic process in which you call on and connect the ideas that you think will get you where you need to go. If the ideas that you think will get you where you need to go tend to be the same set across a bunch of different

contexts, then we see what we'll call stability. And so us, as chemists, see like energy is a part of how we explain everything. So some sort of structure energy connection is probably going to weave throughout a lot of the different contexts we might explain. For students, that sort of broad utility is not always so apparent. And so this, you know, to speak to what both Bernadette and Judith, were mentioning, this is something that we can build in to how we create learning environments, what we emphasize during class, what we emphasize reward on assessments and so forth.

Justin 56:33
So, thank you, Ryan. I did see David's hand pop up while you were answering his question. So I just want to give him the mic in case you ask any follow up or anything but I just gave David the mic.

David 56:46
Okay, just to follow up on your answer. Wouldn't you say that our job as instructors is to help students to learn to think like scientists in a more process oriented fashion, where you consider all possibilities as you work through a problem, rather than allow students to just keep haphazardly doing single or just dual factor thinking when there might be four things they should consider and sequence.

Dr. Stowe 57:15
Sure, but you've got to build to that. So just this idea of like, like molecules interacting, in even one or two ways leads to this thing you can see that's not a major emphasis of many chemistry classes. And so building from there to these, you know, very much multi parameter systems where you've got four or five different variables that you can consider. That's got to be a progressive process. But absolutely, of course, we think about all sorts of different system parameters. Can we predict products or explained distributions of products or talk about structure, property, relationships, things like that?

David 57:50
Yeah. Well, I'm just my point. would be, should we shouldn't we model that type of thinking through Wow, rather than this slow sort of build up of accumulation of what I call factoids. Before we ask them to start explaining things

Dr. Stowe 58:12
I think if you start with a really complex explanation, and students have never had a chance to explain full stop, it's going to be overwhelming for a lot of students.

David 58:20
Yeah, I'm not saying start at the most complicated explanation. It's just you work through the physical stuff. And usually you go through the chemical you build that up as you go.

Dr. Stowe 58:33

Yeah, I mean, it's, yeah, I think I think we're on the same page. It's just students have to be part of that building. And so just, you know, one of us doing that construction of explanations without ever having students do so that can be that can be problematic.

David 48:45
That's the other fight. Getting them to do it.

Dr. Stowe 58:51
Well, yeah. Thank you

David 58:53
I think it can be done. Of course. Thank you.

Justin 58:56
Thank you, David. Thank you Ryan. We'll go to Bob next who has his hand up again. So I'm going to pass Bob the mic.

Dr. Stowe 59:05
Okay, I will then I will listen instead of read. Play, Bob.

Bob 59:09
Hi. Love the presentation. I certainly totally agree with everything you're talking about. My question is, you're obviously doing this at scale. And that's going to take a lot more time to grade than the automated kinds of multiple choice grading that many of you know large introductory core courses apply. So what sort of help do you get into your university? Are they regularly supporting with graduate assistants that help with this kind of grading?

Dr. Stowe 59:41
Well, the short answer is yes. And I also want to thank you for that question, because we have to acknowledge that meaningfully giving feedback to these sorts of assessments is non trivial in terms of resources. So we hire a small army of really great undergraduate graders as well as some graduate students and of course, we have our TA team. So in organic there are between three or four of us depending on the semester that collaborate. We will have an exam next week to right around 700 students and a little higher right around I don't know, 35 to 40 graders in total. So it's a it's a sizable undertaking, to be sure. However, I would strongly advocate that it's worth it if you can, if you can manage it. I recognize that there are many places where those resources simply aren't available through no fault of the instructors and so it's it's worthwhile to think about, are there ways that are better than just asking for numerical answers or factoids that are still less resource intensive. You know, where you have some sort of more elaborated stem of an explanation and people are filling in the various bits that they think are interacting instead of writing out the whole thing, which is harder to grade.

Bob 1:00:48
Yeah, but I have to say your, your approach is much better.

Dr. Stowe 1:00:53
Well, thank you, we were trying.

Justin 1:00:58
Thank you Bob. Um, I see one more hand up and we are approaching a little bit after two now. So we'll probably make this last one but I'm going to give the microphone to Mr. Tung.

Mr. Tung 1:01:33
Hi. Can you hear me?

Dr. Stowe 1:01:35
Actually a pretty faint

Mr. Tung 1:01:37
work we do know like educating the students on everyday life, because I play very less emphasis on memorization but this simple example from inorganic chemistry which is, I teach organic chemistry, but I asked the students not periodically in the hallways know how would you know calcium carbonate is insoluble and and then the thought no, because it's only one says you know sometimes giving different answers No. So then we discussed know that we look at everyday life know that say about a person or when it was soluble would be her model, capital building and how would marine still exist life exist. And how about animals which lay eggs? No, how will they survive? Or then we come back here, then you teach her in the highest in the classroom. Family schools would have not been able to write with the chalk up from like, going from everyday life? No, that has been really because in our school, we have to keep on reinforcing keep on reinforcing orders because of covid I got many students from J Chem. A very good group, but they had no concept of hydronium ion when I started working on Chapter Two on polarity and resonance electronegativity so so I try to apply from, from everyday life and thank you and I enjoy your presentation.

Dr. Stowe 1:03:08
Thank you and I want to, so, that’s an important point and I want that I think the community still doesn't have a good sense of how to do properly.

Mr. Tung 1:03:20
I would ask a long time ago

Dr. Stowe 1:03:23
Oh, great. Cool. So this idea of I've talked about phenomena right? So kind of want to explain how and why things happen that you can observe. And I think that broad brush can pay most of what happens in the chemical sciences. There's a follow up that the community doesn't have a good answer to which is what phenomenon? Why? Right. So we talk about everyday life, what sorts of observable occurrences are worth unpacking, and can chemistry help us understand? And how do we ensure that the phenomena we focus on are both important and not like horribly

complex? Because of course, so many things at the molecular level are really, really complicated. And how do we scaffold these phenomena that we hope intersect in meaningful ways with good everyday lives? Those are all very interesting and important questions that I don't have an answer to, but I think are worth considering. I'm certainly interested in investigating in the years to come. I did see a question about how I grade assessments so we create rubrics and those rubrics are targeted at ideas and connections between ideas. So in the past question, where we were thinking about the ester system versus the acid chloride system, you would have some points for saying the ester system is lower in energy than the acid chloride system, and there would be some further points dedicated to talking about the better orbital overlap between the P orbital on oxygen in the carbonyl pi system relative to the larger P orbital on chlorine and a carbonyl pi System. And so we try to build them in such a way where if you are expressing some productive ideas, you are sort of acknowledged for those ideas and given some credit, and then we keep building points atop that initial foundation. And so if you express the models and ideas that we expect fully then you get all the points, but we have a rubric that we use for that, that we create together with our TAs and we refine in the context of actual student responses because you know, no rubric actually fully survives encountering real student responses, so we're adaptable. It sure would be, yeah, so this idea of having questions available that are explanation focus, I should add that there's a paper we wrote about, god it was a year ago now I think... it's on that we were able to maintain emphasis on explanations when we had to pivot online. But the SI to that paper is like all of the curriculum materials we have for organic I think it's 700 pages long or something. There's a table of contents, there's smaller parts, but that has a ton of really good resources. And if you'd like more information about any of that, just send me a note. Happy to provide whatever you're interested in.

Justin 1:06:06
Ryan, you know, maybe on that note, it would be great if you could post your information for folks to contact you in the chat. Seems like we have a lot of great questions from the audience. That may require some, some discussion and, you know, be great for folks to contact you and reach out to you. So Ryan, I really want to thank you again. We're a little tight after hours so I do want to wrap things up and just repeat some of the information for those of you that may have missed it before. So Ryan just posted his information and email address in the chat if anyone wants to reach out and ask any follow up questions or schedule some additional time to discuss how things are going in your research or classes, with him. And for those of you who will want a recording that will be sent out and for those of you who specifically want a certificate, please email us directly at learning@101edu.co. This is the address we posted in the chat, however, if you also want to quickly find it, if you reply to any of the emails that we've sent out about this webinar, it will go to that address as well. So that's also a way to reach us. So either way um, if you want to send us a new email or reply to one of the reminders or sign up messages that you engaged with before, please do so. And then I'll give one last reminder about our upcoming events. Number one, our mini sessions. We're running 3 different types of mini sessions and repeating them over the next two weeks. These are going to be hosted by our team, talking about ways instructors are taking advantage of our platform, Chem101 to activate student engagement , work with students who have that diverse and differentiations in backgrounds and skills, and also how to kind of make homework more of a learning experience. And then we do

have that separate event, specifically for those of you who are teaching organic chemistry, that's coming on the 17th, Friday December 17th at 1 PM EST. This is going to be specifically on new technology we are unveiling to help students learn and master arrow drawing and electron pushing in organic chemistry. Really excited about that. I'm going to be personally hosting that one, along with my colleague Amanda Cutney who runs our content team. So with that, I'd like to thank Ryan again. I will also post the links to sign up to those events in the chat one last time. And we look forward to hearing and seeing many of you in future events. Thank you again for coming today and participating in this wonderful series. Thank you Dina as well for putting these together. We'll see you all later, and good luck with finals and the remainder of the semester and have a great holiday season. Talk to everyone later.