Justin

I do see that there are a few more people coming in through zoom, but I know we have a really exciting presentation today. Don't want to keep people waiting too much longer. Hello, everyone. Good afternoon. Good morning, wherever you may be joining us today. Welcome to our chemical misconceptions webinar, which today is going to be hosted by Dr. Vincente Talanquer. My name is Justin Weinberg. I am one of the founders and CEO of Chem101 And as a chemical engineer, as a former core mechanical educator, I am just so excited and grateful to have Dr. Talanquer sharing his expertise and insights with us today. I know it's long been our mission as a company to support chemical educators in the work that you all are doing to help students develop a conceptual understanding of chemistry and an enthusiasm for learning subject matter. So before I begin, I do want to tell you a little bit about our speaker as well as this entire webinar series that we're starting today. So today is the first part in a three part webinar series that is going to focus on addressing student misconceptions and chemistry. And I'd also like to give a big thank you and shout out to Dina Borysenko who is a faculty member over at Milwaukee Area Technical College, who in her limited spare time helped us develop and put together these three educational (?). So Dina, I know that you're here so thank you very much. Now as chemistry instructors, that I know many of you are here today, you've probably noticed certain common pain points and misconceptions that students tend to experience when they go through any typical chemistry course. I know this is something that originally drove me to develop and create Chem 101 when I was a graduate student, and over the years, myself and my team have developed tools to help students overcome barriers and master skills like dimensional analysis, drawing Lewis structures, practicing nomenclature, chemical equations, and much more. But there's always more to learn and always ways to improve how we teach and how we work with students. And to help further educate us and help us further understand how we can understand our students thinking, we turn to Dr. Vincente Talanquer for today's presentation. So I'd like to introduce Vincente. Vicente is a Distinguished Professor of Chemistry and Biochemistry at the University of Arizona and is also an educational researcher. He received his bachelor's, master's and PhD all in chemistry from the National University of Mexico In Mexico City, where he worked as a professor until coming to the University of Arizona in the year 2000. Vincente is a recipient of numerous prestigious awards for teaching excellence and in chemical education research. Three of them include the ACS award for achievement in research for the teaching and learning of chemistry, which he received this past spring, the Educational Research Award from the Council of scientific society presidents and he's also been named Arizona Professor of the Year. Vicente is also the co-founder of the chemical thinking curriculum. He has also published over 50 articles in peer reviewed journals and over 10 textbooks, for which are the elementary school science textbooks used by students all throughout Mexico. So I'm going to hand it over to Vicente to give us his great and informative presentation today. Before I do that, I just want to quickly mention that we are going to have a live chat going on today's webinar, I think Vicente is planning to engage all of you in the chat and ask questions and hear your thoughts. So I do want to point out that function is available so feel free to post anything in the chat that's come into your mind when you do that, it'd be great if you could all send your comments and questions to everyone, all panelists and attendees so we can all see what what you're thinking about and we can all kind of bounce off each other. So just make sure to change that setting so we can see it but everyone else can. So with that, I'll hand it over to Vicente and he can share his screen. Vicente, it's all yours.

Vicente
Okay, um, thank you very much. Can you see my screen now?

Justin
Yes, we can.

Vicente
Okay. Well, thank you very much for the invitation. It is a pleasure for me to have the opportunity to share some of the ideas and results from our research. As it was mentioned, I am at the University of Arizona where I have the opportunity to come to conduct research on particularly recently in chemistry. I was always interested in learning issues in our discipline. And we also use the results of that research to develop educational approaches that we hope will help students to develop more meaningful learning. We have the challenge that many instructors in public universities face that we work with very large number of students in our classrooms. So we try to develop strategies that can help us address the students misconceptions in those context. The central goal of my talk is to share with you, kind of, some of the major findings of our research on student reasoning in chemistry, that are, in my perspective, provide insights into the origin of many of their misconceptions. There's plenty of evidence not only in chemistry education, but in science education in general, that our students come into the classroom with preconceived ideas about the properties and materials of objects and substances in our world. And some of these ideas are not aligned or differ from the scientific accepted ideas and we tend to call this mismatch ideas, preconceptions, misconceptions or alternative conceptions. I will be using the term misconceptions, but I should acknowledge that there is a lot of debate of what is the best way to refer to these mismatch ideas that the students bring into the classroom that do not match with what we call them, accepted ideas by the scientific community. There are, I would like to point out that there are many review papers and there are books in which people have very clearly summarized some of the most important misconceptions that have been identified through chemistry education research. I'm pointing here to our review paper by Mary Nakliye. That is quite old by now. 1992 is maybe one of the first review papers that was written on this subject, but there are already books, one by Keith Tavor on chemical misconceptions, and one on by Dr. Berger, that in fact he will be presenting the presentation next Friday. And in these different resources you can find what I will call the result of conventional approaches to looking for misconceptions in our students. So the typical approach is researchers identify a central topic or area of interest. They identify the kind of the way we teach it, and then they analyze the difference between what we would like our students to learn and what they actually are understanding or the learning that they manifest. So for example, it is very common that we want to teach phase transitions, we want our students to understand that during a phase transition, there is no change in the chemical composition of water. But however, after teaching in many situations, you observed that many students believe that actually not a phase change is a chemical change and that water gets separated into hydrogen and oxygen. So that's one example of a very common misconception that has been very well characterized in the

literature. Another example is we want our students to learn about bond energy. The instructor may be very careful in teaching about how during the formation of a chemical bond or the breaking of a chemical bond there is changes in potential energy and chemical energy. And our students in the course believing that during breaking of chemical bonds nor energy kinds of kinds come out of the bonds. So that's another very correct, very well characterized chemical misconception. And they are also misconceptions related to how students interpret graphs. For example, recently there has been work that shows that if we want our students to understand reaction coordinates, we may present these graphs and we would like our students to identify which step in that reaction is faster or slower. And what you find out is that the system to pay attention much, much more attention to the width than to the height now of the representation and so we are very aware that there is in fact a long list of chemical misconceptions that have been identified in diverse groups of students in diverse contexts.

So, in my talk, I am not going to go through, kind of the different categories of misconceptions that have been identified. That has not been the approach that we have been followed in my research group to look at misconceptions. What we have been more interested in is why is the origin of these misconceptions, how is it that they emerge? Why is it that we have been interested in that? Because we believe that it is much more productive to try to address the origin and the cause of the misconceptions than to try to target every single misconception or as a teacher it is almost impossible to know what are all the misconceptions that our students are going to have. And to try to create opportunities to address all those misconceptions. So we have been trying to identify or under the belief that if we know more about what is the origin of these misconceptions, maybe we would be in a better position as instructors to help our students overcome them. So in our research, we have claimed and I think that we have demonstrated through our research that many, I'm not saying all of the misconceptions, but many of the misconceptions that we have seen in chemistry tend to emerge from students applying implicit or naive or common sense ways of thinking. And we have characterized or categorized these implicit ways of thinking into two main categories. One has what we call assumptions that the students make about the behavior and properties of substances and matter in general. And the other one has to do with naive ways of reasoning that we are going to call intuitive heuristics. So what I'm going to do during my presentation is to walk you through in a certain way through the results in this area. Particularly, I'm going to start with assumptions and then I'm going to move through heuristics. So the first thing that I would like to do is convince you that having intuitive assumptions about the behavior of the world is not something that only our students have. Everybody, every single human have assumptions about the behavior of the world. So I'm going to do kind of a thought experiment. I would like you to look at the experiment that I'm going to make on the screen and I would like you to think, how would you explain what you see? Okay, so I'm going to repeat the experiment. So maybe in the chat, someone can type, how would you explain if someone asks you “why is... what is happening here?” What would be your explanation? Or maybe we can unmute someone if someone wants to participate. I'm not necessarily know what would be the best way to... Okay, the bigger ball hits another smaller ball. There is okay, there's a smaller ball. Okay, there is maybe a perspective, it's a question of perspective in the image. Some made somehow the ball got the squeeze. No, maybe there is someone behind the screen there squeezing the ball and making it, making it small anyway. So as you can see, when I ask a question about a phenomenon, people come up with explanations based on what they see, their prior knowledge but also based on assumptions that we implicitly make about what we see. If I had told you that this blue, this yellow ball was an electron, maybe your explanations would have been different because you have made different assumptions about the behavior of electrons versus the behavior of a real object, a ball. So there's many research in cognitive psychology that shows that humans have implicit assumptions about how objects behave. Now, we tend to assume that they can move in continuous trajectories that they persist over time in a space. So we don't believe that they both suddenly know without any reason with a string, for example. So that's what I call intuitive assumptions. And we have been working in chemistry and generally in science education to try to figure out what are those intuitive assumptions that get in the way of learning chemistry? And as I said, everybody has assumptions, not only in chemistry. If I were going to ask you what how would you explain the different phenomena that you see on the screen, it is very likely that if you're not an expert in that area, you would go, you would come up with an idea that is not necessarily close to the scientific idea and that is based on your interest assumptions about how things behave.

Vicente 14:16
So what are the inferences and assumptions that we have identified? So we have, through our research, identified five main assumptions that our students tend to make about the behavior of substances and chemical processes. We have given them a name, and I know that the names are kind of obscure, but I'm going to try to explain what they mean in a second. And what we claim. What we claim and I think that is not only our claim. There are many researchers that, that believe that this is the case, is that these assumptions work as the ground in which students construct their ideas. So imagine that you have in two assumptions or students have in two that some assumptions. They go into the classroom, and they receive some information or knowledge, and they assemble pieces of knowledge. And then, using these assumptions and these pieces of knowledge, they use heuristics to make sense of the world. And they create, in some cases, monsters. Now because they put these pieces together in different ways very dynamically based on these assumptions that are not necessarily the correct assumptions about how the world behaves. The idea is that misconceptions are fluid. We cannot assume that a student has a misconception. The reality is that many students just come up with answers on the spot, not on real time, just to try to make sense of a phenomenon. And of course, they rely on this intuitive assumptions, this intuitive ways of reasoning and also whatever pieces of knowledge they have gathered, nor through their exposition in chemistry or science classes in general. So let me walk you through one other, what we believe are the most common assumptions that interfere in chemistry. Now, many of these assumptions have to do with how we build a structure property relationships. That is critical in chemistry. Now, one of the things that I was, that we want our students to learn in chemistry is how to connect the suit microscopic structure and composition of matter to the macroscopic properties that we observe. So imagine that I would ask you, why are the feathers of that bird multicolored? How would you explain it? Well, if you don't know about it, very lightly, you'd imagine that well, maybe it's because the feathers contain some kind of blue or green pigment. Well, that assumption actually would be a misconception in this case. So, but we will be relying on what we call two very important

assumptions that humans make about the composition of substances or materials. That, one is called inherence. That is the subcomponents of the material that we are observing very likely have the same qualitative properties of the macroscopic object. So we transfer the macroscopic properties to the sub microscopic components. And second, we assume that the properties of the macroscopic object are just kind of a weighted average of the properties of the individual components. So it's, we imagine that the world is made of mixtures. That's essentially what we imagine. And then, if we know the purpose of the components, we can predict the properties of the mixture just by imagining that the properties of the mixtures are going to be the average of the properties of the components. So we have tested these assumptions in many conditions. So for example, so before I show you the results, this this view, notice in this view that the properties of matter in marriage are the result of just the simple average of the properties of the components is very different from the view that we would like our students to understand in chemistry that is actually that the properties of the components are quite different from the purpose of the macroscopic object, because the properties of the macroscopic object emerged from the interactions between the millions of particles, and those interactions on the dynamic movement are going to determine the properties of the macroscopic object, but it's impossible to predict very easily what those properties are going to be just by looking at the properties of the individual components. So we have done a lot of research in this area, different questions and different moments with different groups of students. This is an example that I like, because maybe it's the first question that or the first research question that I post, when I engage in chemistry location research looking for these intuitive assumptions. We ask our students this hypothetical question. We said "imagine that you have a substance that is blue and a substance that is yellow. They are going to undergo a chemical reaction and you are going to predict, you are going to produce a new substance" and we show them kind of the at the microscopic level what may be happening and we asked them "Can you predict the color of the product? Can you tell me what is going to be the color of the product?"

Vicente 19:18
And we have asked these questions to students entering the university finishing the first year of of Gen Chem. Finishing the first year of Chem, finishing their bachelor's, or in graduate school just to see what answers students have. So do you have a sense again through the chat of what would be the most common answer that the students will produce if they are using their intuitive assumptions of additivity and inherence. So it would be great, yeah. So if we assume that, that they are the way they think, that is kind of the answer that you would expect to see. Well, I would like to show you the results so that you see that you are right. And you can see that entering gen chem around at least this is at my institution, maybe your institution is different, but at my institution, entering gen chem 70% of the students would choose the green option. After one year of Gen Chem, not many have changed their idea and it takes a long time and this is not a long longitudinal study. No but you can see that it takes a long time to to be able to overcome this way of thinking. Now, you can place this question, now you can maybe challenge the question and say maybe the question is deceiving and et cetera. But we have done this with a variety of questions. Now, we know that students interpret questions in different ways. And so you have to be very careful on what you infer from what the students answer. We have done this by asking the questions, interviews by asking the questions through surveys and

questionnaires. So for example, in this case, if someone has these inherence additivity assumptions in their mind and you ask them which of these substances is going to be shiny and malleable, which one do you think they would choose? If again, they are based basing their ideas on these ideas of inherence of additivity? Which one of them do which thing that they would predict is shiny and malleable? So you can see, you can predict what actually what we see. And again, you see this persistence during the first two years of teaching chemistry in which the outcome doesn't seem to change much, independent of the instruction. So this is just showing how difficult it is to overcome. Intuitive ideas are about the composition and the properties of substances no matter how much chemistry you are being presented with. We have also looked at assumptions that have to do with how people explain the behavior of chemical processes. We also want our students to be able to make predictions about given the composition and structure of a set of a system. Can we predict its behavior, its chemical behavior? And again, I could show you an example not from chemistry in which people tend to have many misconceptions. If someone asked you why birds tend to use flying. This behavior pattern is very common that people think that the bird on the front is the leader and the other ones are following and that would be a misconception again. But that idea emerges from assumptions that we have about how processes occur in nature. And in general, they are very, two very strong and very difficult to change assumptions. One is that we call centralized causality that has to do with the idea that in general processes are always driven by an active agent, by not like the leader, that acts or hinder the behavior of max or of more passive agents. And they also very strong assumption that the directionality of a process is determined by the goals or the intentions of these activators. So that processes occur because there is an agent that wants to achieve something. So we again we have explored these assumptions, different contexts, different questions, different types of students and different levels of preparation. And this assumption is very different, again, from the one that we would like our students to develop through our courses is that actually, chemical processes are random processes that are biased and they are biased by energetics and in tropics. But, but that you cannot assume that there is an active agent acting on a passive passive agent and that you know the outcome is because they activated wanted to become more stable or wanted to get an octet of electrons or wanted to be happier, etc. So we have asked our students again, many different questions oriented in this direction.

Vicente 24:21
And for example, we have asked, imagine that you have two substances and or two molecules or two chemical entities and A is more and you can substitute in the three axes, whatever you want... more polar, more electronegative, bigger... anything that makes it different from B that somehow gives the sense that is the most important the most active entity in the system. And you ask them okay, when the substances are mixed and react, which one starts the reaction? And what you find through doing this, is again, if you in fact, no matter at what level of expertise you ask the question, around 50% of the population believes that the most active agent starts the reaction. And you can... this is a question of, for example, how the reaction starts. If you ask why the reaction happens, and in this case... this reaction… this particular resource come from asking students to think about oxidation reduction question and as electrons can transfer in this reaction, why those electrons transfer between the entities? Well, you can see that the majority

of the students choose the option that is related to... well the transfer happens because the substances want to become more stable, that is kind of the teleological option, rather than the most chemical option, the most known, that they accept a chemical answer that will be that the electrons get transferred randomly, but there is a bias in the transfer due to differences in potential energy for example of the entities that are interacting. So in general, we have a lot of evidence that these type of assumptions are persistent, they are very difficult to change. They don't change with instruction very easily. And they are the origin of a variety of misconceptions because these ideas that are pervasive in our students' thinking get applied in a variety of contexts, and lead to sometimes incorrect answers. In general, we have found that whenever we put our students in a situation in which there is an asymmetry between the things that are interacting, as I said, one is larger, one is heavier, one is a stronger, or one who has a larger electronegativities, more nucleophilic... Whatever you want to whatever properties you want to to choose, student's will use that to guide their thinking and assume that that is the relevant entity to use in their thinking that that entity will drive the outcome of the process and very likely that why that happened the process happened is because that entity wants to achieve something that would would benefit in some way. Now, the assumptions that we make are not the only thing that are relevant. We may have assumptions about how the world behaves, but what is also relevant is how we use the information that we have to make decisions or to construct inferences to make predictions. So we have also been paying attention not only to kind of the background ideas that the students have, but also how they reason with the information that they get. And that that takes us to the realm of decision making and there is a lot of research on how humans make decisions. And one interesting area of research in decision making has to do with what is called reasoning heuristics. So again, I would like to show you that having heuristics or using heuristics is not just something that students do. Every single human relies on heuristics to make decisions. So heuristics are what is called frugal mental strategies. That means they require little information and little time to make the decision. And we apply them commonly in our daily life. So I'm going to put you up, I must ask you a question. Okay. I'm going to send you to a supermarket. Imagine that you are in a foreign country and you go to the supermarket and you want to buy milk. And you're getting into the supermarket and you see two containers of milk from different brands, and you want to choose one. Now, this is a foreign country where you don't speak the language you have never drink, drank milk in that country so you don't have a sense of what to buy. But what I would like you to do is I'm going to show you that two, two kind of boxes of milk and I want you to tell me, what is your gut reaction, just your gut reaction. Which one would you buy? So even under those conditions, which one would you buy?

29:23
Just tell me in the chat which one do you buy? Just gut reaction. Okay, so as you can see many, many people just go with Lati. That's a typical response. Even when we do not have a clue of what not actually the milk contains, etc. And the question is why? Why we make these decisions? I could also ask you a question like this one... Who of these two people would you trust? And again, you don't know anything about these people but be likely your bias to select one. So the question is, okay, what is going on here? So we were very interested to see in, through our research, to what extent our students were relying on heuristics to make decisions.

So we have put our students in a variety of situations in which we ask them to make decisions, which are some substances more soluble with substances more reactive with substances and a stronger acid. If you think in chemistry, our students are asked to make a lot of decisions that have to do with containing substances and their properties. So what we have found is that in decision making our students rely a lot on what is called heuristic reasoning. And heuristic reasoning works more or less like this. Imagine again, this is another example. Imagine that I would ask you, in which, which of these two boxes would you select, that has the highest probability to get the white ball out? And I'm going to give you $1 million if you select the right box. That the box that in which you have the highest probability to get a white ball if you put your hand in. Well, when you when, when you ask that question, and you don't give people a lot of time to think about it, most people select the one that has the two balls. Not the one on the end, you never know which is right to left, on the right for me. So why is that? Well, because when we make decisions the way heuristic reasoning works is by doing this... we first look at the system that we are interested in or at our options, and we identify the most salient feature and the most salient feature is typically the most explicit difference between the two things. And in this here, in this case, the most explicit thing, the difference is that well, I have more balls on the right than on the left, and I have more white balls on the right than on the left. So that's the first thing that we notice. Then, based on what we notice, we see that if we can also see that difference to the decision that we can that we have to make. So in this case, well, I have to make a decision on where it is more probable to get the white ball. Well, having more white balls seems to be associated with having more probability. And then we just unconsciously substitute a difficult question. And the difficult question is you need to take the ratio, not just go with the amount you need to take the ratio. But that's a difficult thing, takes more time to process. Well instead of doing that difficult processing we just go with "Okay, there are more whites there is likely that the option that I'm going to choose". So this way of reasoning is pervasive in chemistry. We have plenty of research that shows that our students rely on this type of heuristics to make decisions before and after they take our courses. Now for example, as I said, we have asked our students to make decisions so "which one is more soluble, potassium iodide or sodium chloride?" And we are expecting our students to recognize that this is ionic compounds, that they can look at the charges and the size of the ions, think about the interactions that they are in… Based on that they can at least build a plausible explanation. And what our students do is not necessarily that. What I was used to saying, "okay, sodium chloride, potassium chloride. I recognize sodium chloride, sodium chloride soluble in water, that for sure is my answer."

33:29
Or for example, we could ask them which of these two substances generates more energy when you burn them? And again, we would expect our students to think "okay, what is going to happen when these things react with oxygen?" Maybe write the chemical equation, maybe think about the stoichiometry, maybe make a calculation of the energy that gets released by the bond, the nature of the bonds that gets formed and broken, etc. And that's not necessarily what our students do. Our students would say, "okay, glucose exane… what do I know about this thing? Glucose… I have heard that, you've seen food and I use it to produce energy. Very likely glucose." So those are tend to be the best options but sorry, the options that they choose and unfortunately, in this case no that are not actually the best options based on the chemistry that is

behind. So but again, these are very deceiving strategies, that bias our students reasoning, and they are quite difficult to change. Again, or to help our students modify. So this particular heuristic of going with what you recognize is very well known in the decision making literature is called the recognition heuristic. And what we tend to do is just make choices based on the things that we recognize or we have heard before. We have done research in this area, we have identified three main heuristics that our students tend to rely upon to make decisions that sometimes lead them to the right answer, sometimes not. One is recognition that I just presented similarities based on identifying things that have similar characteristics, explicit characteristics, what you can see, the same number of atoms, same types of atoms, things like that. And the other one is one recent decision making that is making the decision just based on one property that is the most salient and ignoring any other factors that may be relevant to make the decision. So for example, imagine that it's a question again, that we have done using our research. We put our students to make decisions. Imagine that you want to build a camping burner and you have to make a decision between which substance would be best to use as your fuel and you present CH4 and CH4O. Or you could present the question as saying oh, one you can use natural gas or methyl alcohol. And depending on how you present the question is the choice that the students make. So for example, if you present them as the chemical formulas, the majority selects that one and if you present it as natural gas, the majority selects that one. And those when you do the interviews with the students of why they selected that you realize that they are not guiding their reasoning by the chemical knowledge that they may have. They are just relying on heuristics. In most cases, for example, in the case of CH4O, many still selected because it has oxygen so it's a very explicit distinction. That one has oxygen, they associate oxygen with burning and they say :oh very likely that is better at burning." Or in the case of presenting the names of the substances... natural gas... Again, humans beings tend to be biased towards natural, believing that is better for some reason, so that simply biases their thinking in that direction. So students are quite sensitive to explicit features that they see or knowledge that they have or ideas, beliefs that they already have about the nature of substances or processes.

37:16
So, we have a challenge. Our students have certain core assumptions very intuitive, very strong about why and how things happen or why and things have certain properties. And those assumptions and ways of reasoning are quite different from their assumptions and ways of reasoning that we would like them to develop. The idea that there is random behaviors that there is emergence of properties, that we need to do some more analytical reasoning based on the careful analysis of the structure and composition of particles in a system. So these things collide with each other, and misconceptions emerge from the collision of what the students tend to do intuitively and what we are asking them to think that is quite different. And then they merge it and as I said, they create monsters. Now those monsters, those conceptual monsters are not necessarily stable. Those conceptual monsters which change shape depending on the question that is being posed, the context, what the student read that morning that could influence how they are thinking. So to believe that the misconceptions that the students manifest are kind of fixed and permanent things is not aligned with what the research shows that these ideas tend to

be. Ideas that the students manifest, they are not fully committed to those ideas. They are just things that they built on the spot to try to deal with a task at hand.

39:00
Okay, so just to close... I don't want to end this with the sense that there's nothing to do, we cannot change anything, it's difficult or it’s going to take forever to make these changes. We have been engaged in trying to improve the way our students think. I'm going to tell you a little bit of the things that we are doing and the level of success that we are having. I want to be very honest with you and also to show you how challenging this may be. We have been changing our curriculum particularly in the general chemistry sequence, we recognize that what we were doing was not helping our students develop the type of thinking that we wanted. We, we have always said this is our mantra that chemistry is more than a body of knowledge. Chemistry is very powerful of knowing the world, thinking about the world and acting on the world. And that so instead of focusing so much on what our students are learning in terms of information, we need to focus on what our students are learning in terms of developing productive and ways of reasoning and acting and decision making. etc. So we have tried to change the nature of the curriculum so that we don't put so much emphasis on content. That doesn't mean that we don't emphasize content. It's not that we don't start there. We tend to guide our curriculum by questions. So we want our students to recognize that every piece of knowledge that we are asking them to learn is useful because it helps provide the answer to relevant questions. We have identified a set of what we call essential questions that guide our discussions and work with the students. So what are these things made of? How do we know what things are made of? What properties do they have? How do we know what properties they have? What, how and why processes happen? How can we control those processes? And also what are the consequences that cause best benefits and risk of engaging in chemical activity? So we have a curriculum that is guided by questions. We work answering those questions in relevant context, I think that contextualizing has been shown in research that is central to get a student's attention and motivation. And attention and motivation are critical to change the way people think. We have changed the nature of the activities that we do in the classroom to try to emphasize this need to pay attention to data, pay attention to the information that you have in a system, use that information, combined with chemical models. So we bring this idea that there are models that are developing chemistry that help us make sense of the information that we gather. And then that we should combine the information with the models to make sense of what is going on and build arguments, explanations, etc. We have changed the nature of our classrooms to engage the students in more active discussion with the instructors and with themselves so as you can see, we teach these very large classrooms now in kind of very flat spaces where students can work in small tables and have more interactions and work on these activities.

42:19
We try to make the students thinking as visible as possible so that we can provide feedback on a regular basis. We use whiteboards, we use a computer that can be projected on the screen so that they can share their ideas with their classmates. So we are emphasizing this idea of formative assessment as critical to to make a student's ideas visible to us so that we can provide feedback for more guidance to them, and we are scaffolding their thinking. We

recognize that if we want the students to think in a particular way, we need to make it explicit to them, how different is the way they think from the way that we want them to think so we provide we particularly in the general chemistry course that is a first introductory course we start for the students ideas by saying “please build this model, build this representation. Let me know what you think is the most important feature here. Then how would you use that to make your whatever inference explanation argument.” We try to guide the students and then we remove the scaffolds little by little, but I think that is critical to recognize that developing what we call chemical thinking is challenging, particularly if you think about what the students bring with them to the table and that we need to be more explicit in guiding our students to the type of thinking that we want them to, to to acquire. Now how is it working? We have developed and this instrument is open for everybody to use it. You just go to this site on the screen. We develop what we call an intuitive quest chemistry questionnaire inventory, in which we test these intuitive ideas with 20 multiple choice question questionnaire we ask our students to complete before entering Gen Chem and then at the end of finishing gen chem so that we can see progress or not progress, in changing this intuitive ways of thinking. The type of questions I'm showing you here one type of question or some of these questions we have borrowed from instruments that are already out there that prove misconceptions. Others we have developed based in our own research, all of the questions are multiple choice. And here you can see typical results. Now this is a result from one year. Results change year after year. But we typically see a switch from a student's starting in the pre without, average of between 25 to 30. And ending after one year of Gen Chem, moving to between 40 to 50. That also relates semester to semester. You can claim that there is not a big change and that is not a big change in our perspective. We would like our students to improve much more than this. But this is much better than no improvement that we had observed before the changes that we have implemented, In the conventional curriculum before we implemented all these changes, our students entered and ended almost with the same score. So at least we are seeing progression. The other thing that we have seen that is quite interesting in my perspective, is that of course these questions that we do pre and post the students not necessarily are very committed to them in terms of I mean, we give maybe extra credit points for completing them but the students maybe are not investing a lot of cognitive effort in completing this no pre and post test. So we did an experiment. We offered a group of students a different version of the questionnaire. And in that version of the questionnaire, we post the same questions. Imagine that was the same question. But to a subgroup of the students, we told them, we post a second question related to this one. So the question was there and then the second question that we asked is immediately after this, each question we said, “Okay, now we want you to think, look at the answer that you gave, and tell us what answer do you think that would be given by a student that was misguided by their intuition?” So we are presenting what we call a metacognitive or reflective prompt. We are asking the students to reflect a little bit more on their answer. Just by asking them “imagine, just let let us know what do you think would be the answer?” Have a student that just chose just randomly guided by intuition? What is surprising is that we do, do that.

47:14
This is the results for the… in blue, you can see the resulting this IC questionnaire for students with different final exam factories final course grades. So you can see our students that get an A

in the course, get an 60% in the IC after completing the course. Our students that get an F in the course get, like 28% in the IC and you can see that the performance in the IC correlates with the performance in the course. But just by asking this reflective question, all of the students in no matter what grade they got in the class, improve the performance in the IC by 10%. So that means that many times these misconceptions that the students manifest are the result of lack of opportunity or prompting to reflect to be metacognitive about the answers or the explanations that they are given. So this example is showing that we can improve a lot of the thinking of our students just by prompting them to think twice about their explanations or their choices. So with that, I wanted to just conclude saying that I hope that this talk has shown you how we are using research on the student of reasoning in terms of how they make decisions, how they build inferences, to make changes in our practice, and use the results of that practice to conduct more research. That's kind of the way we work. I want to acknowledge the participation of the instructors that work with me in the general chemistry course and of course making all these resources you can see their faces here on top and then the great different guiding students that through the years have worked on our projects on assumptions and heuristics. And with that, I am Thank you. I want to thank you for your attention and I'm open to questions, comments. Thank you.

Justin 49:22
Thank you Vicente. That was a fantastic presentation, I'm sure everyone here including myself, found that extremely informative. You know, it's really amazing to see the body of work that you and your colleagues have produced over the years. I want to open it up for questions. There are a good amount of people tuned in and there is some questions being posted in chat and some comments. Vicente there, there is a question about sort of the impact on sort of multiple choice question in the q&a section. I don't know maybe if you want to take that one first. But I will also invite anyone to use their raise hand function in zoom if they want to ask a question out loud. And we can go through there.

Vicente 50:16
Um, could you tell me what is the question on the multiple choice? I don't think I can...

Justin 50:22
It's in the q&a

Vicente 50:25
(Question) “One way we tried to get around this concerns to assistants displaying their answers and show their analytical reasoning and then evaluate the recent stances. But even when we do this as students are given a multiple choice question. We'll continue to select the distractor answers right misconceptions do this misconcept still persist our students just failing to back.” Well, I hope that I showed that um, I don't think that... I don't, I don't want to say that the misconceptions proceed. But their fundamental reasoning that is driving now that misconception is still persisting in my mind. And that is very it's quite difficult to to change. We have as an instructor's to recognize that changing fundamental beliefs about the behavior of the world is quite challenging. And that's why we need to create many opportunities for students to think

about the same ideas over and over, not just once. We are used to having curriculums that are so packed with content that we don't have opportunities for students to really think very carefully, very scaffold in various scaffolded way, several times in different contexts so that we can change their way of thinking so yeah, I believe that changing… changing the misconception a student can memorize, a student can memorize that bonds… when bonds get broken, they don't release energy. They can memorize that. And we can get satisfied with the idea that oh, yeah, now they know that when you break a bond, the bond doesn't really change energy. But I can bet money that if what they did is just memorize. We can find a question in which their real belief will manifest again because this idea that bonds are like containers, that is, like a natural barrier way of thinking about chemical bonds not as containers of energy. Uh huh. Well, then if you have that assumption, is going to be very difficult that you change your belief that when the container goes broken, the energy gets spilled out.

Justin 52:54
Thank you Vicente. I don't see any hands up. So I just want to if anyone is curious about how that works, there is a raise hand function that you can pop up in zoom. So I see a couple of hands popping up here. While I have this screen share up, I do want to mention that we are providing certificates as well. If you do need a certificate of attendance, please email us at learning@101edu.co. One of my colleagues can put that into the chat. So you can request that there and we are also administering a survey for events that you all would like to see coming up. We have a great site of events coming up in the next two to three weeks, but we're curious kind of what you guys are thinking about what you'd like to see. So my colleagues will also be posting a link in the chat. But I see we have a couple of hands up now. So I'm going to give the mic to Alex Madonnik. Alex, please feel free to yourself.

Alex 54:07
This is a question about an early slide about properties of substances and there were blue balls and gold balls. But the gold balls were labeled blue and the blue balls were labeled gold which is an interesting cognitive experiment but I'm not sure that was deliberate.

Vicente 54:24
Well, when we did when we did the experiment, they the representations were just white, white and black and white. So but for the for the presentation, I choose the colors contrasting colors just to show that we are not representing the blue balls as blue so that the students don't have that be we are not like reinforcing that belief.

Justin 54:54
I see another hand up from Mustafa SOS blir. I'm sorry if I'm not pronouncing that correctly, but I'm going to give you the mic next. Mustafa you should be able to unmute yourself

Mustafa 55:11
Hello I'm joining you from Turkey.I Tetrick University in Turkey. I'm really a thanking to Vincent for this wonderful presentation. My question is a little bit out of the context of the presentation but I would like to ask Vincent about the appreciation of Chemistry Education Research inside

the chemistry department. Because in many places Chemistry Education Research in the chemistry departments are really omitted. It's not appreciated. And I see that his contribution is great into in terms of teaching the chemistry. So what he is thinking about the importance of Chemistry Education Research, or the people in Chemistry Education research area to be employed in the chemistry departments. How this would improve the quality of teaching in chemistry departments. Thank you.

Vicente 56:14
I think that I do believe that chemistry educators in chemistry departments are a great asset. If the department is ready to have constant educator among their business. And also I know many departments in which chemistry educators are very well... very welcome, very well appreciated, and does their work has major impact because it can be implemented. But I also know of chemistry educators that leaving departments in which their work is not valued and appreciated, and those gets lost. So I am fortunate to be in a chemistry department that recognizes that we have research and expertise in Chemistry Education and that we need to rely on that knowledge and expertise to try to improve our teaching and learning. I think that we have shown there many chemistry education researchers not only in the US, like like you in Europe, that have made very important contributions to understanding teaching and learning chemistry. And I think that is difficult. It's a difficult task. We experience a lot of challenges, but things at least for me have been changing little by little and I see I see more opportunities to, to work in transforming practice, teaching practices through the use of research, but it's not easy though.

Justin 57:50
Thank you. So there are a couple of more questions in the q&a section. I want to talk about those next.

Vicente 57:58
Okay, so the next that I see is for the percent improvement slides. How do you account for the fact that humans do better at times when they repeat, becoming better at test taking? Yeah, that's a possible explanation that they were not.... Well, they were asked to think twice about the same question. So that would be considered as repeating. So I agree that I I'm not quite sure that I could be able with this experiment to differentiate if the effect was better at test taking, although, I... the nature of the problem, makes me believe that the impact was stronger for the fact that the question asked them to reflect on what they had answered. More than the fact that had they had to select the answer twice. However, we would have to do more research to answer to differentiate those effects. And the next question is I'm inevitability moving to a week's course. I understand I have to use multi level content recent questions to cover more at once. Is there a strategy to direct? Oh, I would suggest to cut material. Sorry. I know that doesn't answer but we teach too much and we pack too much into a single course. So I would make very, very critical choices on focusing on central ideas, certain central concepts and try to work through them. I would be very happy to have interaction, more extended interactions with people through email or via zoom. That's a very difficult question. We face very, very important challenges when we are asked to teach in very different situations. So I don't have an answer to your question. As I said it's a very difficult question to answer.

Justin 59:52
So we got we'll take one more question. The hand just went down. So do a lot last call for questions. I know we're a little bit after two and I know people have to run in classes and have busy schedules. So a last call for any questions posted in the chat, q&a, raise your hand. Anything for Vicente?

Justin 1:00:23
All right. Well, Vicente, thank you again, so much for sharing this presentation with everyone. I think from the comments that we're seeing in the chat and all the great questions. I think people found this extremely valuable. Just to recap some of the things I've mentioned before. If you are looking for a certificate that you attended today's webinar for any professional development purposes, please email us at learning@101edu.co. My colleagues will again put that in the chat if you want to copy that and send us that request. We'll get back to as soon as we can. We are also looking forward to hopefully seeing many of you at next week's event, part two of this webinar series, where Dr. Hans-Dieter Barke from the University of Munster in Germany is going to be hosting another misconception stock. As you guys hopefully noticed, Vicente referenced Dr. Barke's work in today's in his talk, so really looking forward to hosting that. And in a couple weeks after that, after Thanksgiving, we'll have Dr. Ryan Stowe from the University of Wisconsin, so just Friday's going forward same time. And if you need an, if you need to figure out a link to register, please let us know. We will also be sending out recordings of all these webinars for those of you who register if you can't make these times please register we'll send you out a recording. And lastly, we are doing a quick survey on what everyone thought of today's event, as well as learning about what events you would like to see, coming up next year. 2022 will be there before we know it. So again, thank you again. Thank you guys for everyone joining. Thank you Vicente, thank you, Deena for putting this together. We'll see everyone next week at Dr. Barke’s talk. Thank you