Electronic Supplementary Material (ESI) for Chemistry Education Research and Practice.

Appendix B: Coding Categories for Student Discourse

Categories	Codes	Description	→= Examples of codes from transcripts
Regulative	• Course issue (CI)	Comments made about the course or what was covered	EXAMPLE 1 →F5: Is it just me or does it feel like there's a little less material on this test than on the previous test? →M7: There's a lot less material on this test. EXAMPLE 2 →F3: That's what it said in the book. →F5: Our TA just put the h with the bar through it. →F2: Our TA didn't do anything. →F1: Burris just did the h bar.
	• Managerial/ Structure (MS)	Statements or questions used to initiate, progress, or carry out classroom activities Note: A structured way to lead or facilitate the discussion (e.g., peer leader assigning the collaborative-learning strategy, peer leader asking students to read a problem, students reading a problem, peer leader (or a student) moving students to the next part of the problem set, peer leader (or a student) keeping individual student on task)	EXAMPLE 1 →PL: All right. So this is another one where we're going to split up half and half. I'd like to mix the groups up a little bit if that isn't going to make anyone too unhappy. So Mel, can you switch over here? [Pointing] And you, switch over there. EXAMPLE 2 – *Comment made to initiate the Review* →PL: How 'bout periodic trends? Did you talk about periodic trends this week? EXAMPLE 3 – *Comments made to progress activity* →F4: All right, what do you guys think? Should we retire him? (*Referring to the student at the board)* →PL: Yes, I think we should retire him. Sit down. Any other concerns we want to bring up before we get started on this week's problem set? EXAMPLE 4 – *Comment made by peer leader to encourage participation* M1: Who hasn't started their synthesis essay?

Appendix B: Coding Categories for Student Discourse

		F2: I wrote mine at 11:30 on Friday morning and it was due at 1…. →PL: [...] What do you guys, [M1] and [F2], [think] for, umm, electronegativity?
• Refocusing (RF)	Comments or questions used to re-direct a student's comment to the entire group (interactional, without science concepts)	EXAMPLE 1 M6: And because we know according to Newtonian mechanics that momentum equals mass times velocity [looking at peer leader]. →PL: Would you like to tell your group that? EXAMPLE 2 F1: What am I writing? F2: $p=h/\lambda$ (overlapping speech) →PL: What is [F1] writing up, guys? What are we talking about? [Points to board] M6: Momentum equals Plank's constant over the wavelength. EXAMPLE 3 F3: Um, because Z* decreases for an anion, because you're adding more electrons, and so then that positive charge on the electron is gonna be a lot smaller, so as Z* increases, atomic radii (inaudible). →PL: Not bad. Does everyone agree with that?
• Feedback (FB)	Comments that indicate whether ideas are important or necessary for the topics being covered or to provide positive reinforcement such as whether ideas are correct/incorrect Typically in response to a statement, not in response to a question	EXAMPLE 1 M2: It involves shielding, right? →F1: It involves shielding, yeah. →PL: Yeah. Involves shielding. EXAMPLE 2 F2: […] Atomic radius increases as you go down, and it decreases when you go that way…. [gesturing to the right] →PL: I like that.

Appendix B: Coding Categories for Student Discourse

• Meta-communicative (MC)	Comments about what is occurring in frame (in frame is a socially shared understanding of what students are currently doing) Also statements that act as jokes (relating to the topics at hand) or acknowledgements. Note. Statements that indicate students are paying attention to one another are coded as MC. Many times non-verbal cues are needed to distinguish an "acknowledgement" from "feedback."	EXAMPLE 1 F4: E_p minus the work function. So 7.92×10^{-19} minus 6.6×10^{-19} joules. And those are all joules. What did you get for E_p? F2: Did you get *92* or *95*? →F4: I didn't do it. I will though. I just like to get everything [written] down. EXAMPLE 2 →F3: I left half of my notes in my other binder. That was stupid EXAMPLE 3 F4: Okay, this is gonna be a lot bigger, no matter what. →F3: Mmm-hmm. *(comment indicating that F3 is paying attention to F4's explanation)* F4: So, like, that's gonna be the biggest. F3: So Br's definitely the biggest.
• Meta-Cognitive (MG)	Statements about learning, thinking, or cognitive processes (knowing/ thinking about knowing).	EXAMPLE 1 →PL: I personally think electron affinity is the hardest one to understand. That's just me though. F4: That's encouraging. →PL: No, just, like in high school it was really explained very badly to me - it took me a while to actually understand what it actually meant. EXAMPLE 2 F3: Oh wait, negative means more electrons. F4: Yeah. →F3: Why do I always get that confused? EXAMPLE 3 PL: [What are you working on?] →F4: We're trying to figure out electron affinity. We know the trend, but we're trying to get, like, a better understanding…

Appendix B: Coding Categories for Student Discourse

• Revoicing (RV)	Comments that highlight or readjust another student's comments to provide science concepts or synthesize information put forth by multiple individuals.	EXAMPLE 1 PL: Okay, so velocity goes up. What else goes up if velocity goes up? F3: Momentum goes up. PL: Momentum goes up. M2: Wavelength goes down. →PL: Lambda goes down. F3: Because h/momentum. →PL: So it looks like the smaller the photon wavelength the more energetic the particle. EXAMPLE 2 M1: If you have a smaller lambda then you would have a larger kinetic energy PL: A larger one… M1: Which means you would have a larger velocity, right? PL: What do you guys think? F6: Yeah PL: Okay, larger. →M1: So then, velocity is larger PL: Which means? M1: De Broglie wavelength is going to be smaller →F3: So the smaller the [photon] wavelength the smaller the de Broglie wavelength.

Appendix B: Coding Categories for Student Discourse

Categories	Codes	Description	→= Examples of codes from transcripts
Instructional	• Non-elaborate (NE)	Comments or answers that provide one (or a few words)-word answers; or provide answers, values, equations, or definitions without explanations. Also re-stating what they learned in class.	EXAMPLE 1 F1: What did you guys get for E_k? →F2: I got 7.94×10^{-19}. EXAMPLE 2 M6: Momentum equals Plank's constant over the wavelength. PL: What is that? →F4: De Broglie wavelength. PL: What does that mean? →F2: It's saying that matter has wave-like properties. EXAMPLE 3 PL: How is Z^* on the periodic table? Does it.... →F3: It increases that way, decreases that way.
	• Non-explicit procedural (NP)	Comments that provide non-elaborated information to help one another solve the problem and occur in the context of multiple turns of speech. Consists of swapping information/ideas and can only describe discourse that falls within the Instructional category. Notes: 1. PL cannot be involved in swapping information. 2. If initiation STEP is non-elaborate (NE), then it is coded as NP. 3. Can be a non-linear flow of information that could be used to solve the problem	EXAMPLE 1 – *Building on one another's explanation* F3: But we want it to be ejected right? So we want to set those two equal to each other. F1: Yes. F2: We do? F1: Did we do that before? F2: What? →F3: We don't know *E*. →F2: But if we find *E*. →F2: We could find it. They give you wavelength. →F3: They give you wavelength and the work function, and then we can find the other kind of wavelength. EXAMPLE 2 – *Swapping information* →F4: So that's already written in increasing, so you don't even have to change the order for the next one. Okay. And then, Li, and then Be,

okay, so Be is smaller than Li but not much, so Be^{2+} has the same amount of electrons as Li^{+}, right.
Right. So Li is gonna be the... ummm....
→F3: Li is gonna be smaller.
→M6: So Li is gonna be the sm... I mean, Li is gonna be bigger. Yeah, so
→F4: Li is gonna be the biggest. But, Be, has an extra neutron. I mean not neutron, proton.
Yeah, extra proton. So that's gonna make it smaller.
→F3: Yeah, that's one more than Li. So that's gonna make it smaller, so it's gonna be, that's gonna be the smallest. So it's gonna be Be, Li^{+},
→F4: Li.
(inaudible).
M6: (inaudible). No. And then this has one more proton than this, right?
F4: So, Be^{1+} would have the same number of electrons as that. Be^{2+} has the same number of electrons as Li^{+}. But, Be^{+} is gonna be smaller than Li^{+}, because there's more protons than electrons. You have the same number of electrons, but one has more protons, so that's gonna be smaller. Does that make sense? All right. C. Na, Mg, Al.
(inaudible).
So they all have the same number of electrons.
→F3:

EXAMPLE 3

So it would be Li-, Li, and then Fluorine.
→F4: But this Li is like Helium
→F1: So I think it would be Li- first because that's a negative.
→F3: Yeah because it's going to lose energy. Yeah sorry it took me a
→F4: while.

• Explicit procedural (EP)	Comments that focus on problem formation and include clear or precise procedural directions for solving a problem. Telling someone how to do something.	EXAMPLE 1 →F1: You can use kinetic energy of the work function [which is] $E_K = hv$ minus [the] work [function] EXAMPLE 2 PL: Anybody disagree? [F5] how did you do E? →F3: Uhmm. Ca, S, Cl. It increases to the right and decreases as you go down so Ca is one row down so it is going to be smaller than S and Cl. And then S is to the left of Cl. EXAMPLE 3 →F3: Yeah. So then, if you had one [lone pair], it would be see-saw, if you had two, it would be T-shaped, and three is, if you take this one out, it would be linear. →M3: So, the three in the middle are on a plane, right? And then there's one on the top and one on the bottom?
• Conceptual explanation (CE)	Comments that discuss the meaning of a number; or discuss the meaning of equations; or discuss why or how an answer or equation makes sense; or relate numbers to real life experiences or analogies; or use diagrams to explain understanding	EXAMPLE 1 →M1: So, you know the momentum is 7.31×10^{-22}, and error in the momentum is 5.27×10^{-32}. So the error is like 10 orders of magnitude smaller than the actual momentum. So, it's extremely small. This would make sense because our Δx is pretty big. Where you guys, well you have the same momentum [as we do], but your error in momentum is 5.2×10^{-26}, which is only four orders of magnitude smaller. So, it's actually like a more substantial amount of the momentum. (scientific notation format?) EXAMPLE 2 PL: So, how do we relate the de Broglie wavelength to the wavelength of the [inaudible] of light? →F4: Well, that's the length of the electron being emitted. So, if less energy is being put in to emit the electron, the electron is going to have less energy and therefore, a larger wavelength.

Appendix B: Coding Categories for Student Discourse

• Closed question (PC)	Questions or requests used to focus thinking on particular content or procedures		EXAMPLE 1
		→PL:	So what does that mean, like what is that Lambda?
		M5:	Wavelength of particle of matter.
			EXAMPLE 2
		→PL:	So which way does ionization energy increase?
		F4:	It increases this way [pointing towards the right].
		→PL:	OK. What about this way? [motioning vertically]
		F3:	It's going to decrease, I think.
• Open question (PO)	Questions used to promote discussions or elaborate on conceptual explanations about content or procedures Often phrased as "how" or "why" questions.		EXAMPLE 1
		→PL:	[…] So we have two different wavelengths of light coming in and it looks like 2 different wavelengths for the electron ejected *(peer leader is summarizing students' answers)*. <u>So what can you guys say?</u>
		M1:	As one goes up, the other goes up.
		→PL:	Ok. Do you have an explanation of why?
		M1:	Because when the wavelength of a photon goes up, it means the energy is decreasing. And when its energy is decreasing, it means the kinetic energy is decreasing, because it is going to be closer to phi or the point that the electron doesn't get ejected, and as it approaches that point, the electron has less kinetic energy, and therefore its wavelength is going to get longer.
			EXAMPLE 2
		PL:	What is Z^*? […]
		F4:	The pull of the […] nucleus towards the electrons […] The electrons are being more strongly attracted as you go toward the right, so the radius is going to get smaller as the electrons are being pulled in more.
		PL:	How does everybody feel about that explanation?
		S:	Good. (overlapping speech)
		→PL:	Does it fit as we go down, too? Does that same explanation hold as we move down the periodic table?

Appendix B: Coding Categories for Student Discourse

Categories	Codes	Description	→= Examples of codes from transcripts
Other	• Off-Task (OT)	Statements not related to the course or the material.	EXAMPLE 1 →F3: Wait, what are we supposed to do for that, um, annotated bibliography? EXAMPLE 2 →M6: Guys, I don't know if I'll be here next week, so… →F1: Ohhh… We'll miss you, Mikey. →M7: We'll survive without you.
	• Not Audible (NA)	Statements whose meaning cannot be deciphered because of inaudibility.	EXAMPLE 1 →M1: (inaudible) EXAMPLE 2 → (overlapping speech) EXAMPLE 3 →M6: Because… (inaudible) creates like (inaudible). F4: I do hear what you're saying…
	• Not Codable (NC)	Audible speech that does not fit any above code.	EXAMPLE 1 PL: Everyone who has a periodic table, if you'd all just, like – any form – A, B, C, D… →F2: You wanna… EXAMPLE 2 F4: It has a noble gas configuration. →M7: It's the same as…