Supplemental Material

CBE—Life Sciences Education

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Coding Guidelines – Analysis of Participant-generated Instructional Analogies

OVERALL PROJECT BACKGROUND:

Improving the Teaching of Science at University using a PCK-Centered Professional Development Course

Overall project goal: iteratively develop, test, and research a professional development course for science PhD students at the UZH Faculty of Science called Teaching Science at University (TSU)

Target group: the PhD students who take TSU are typically in their 20s; work full time on quantitative scientific research; career aim is to be an excellent research scientist – teaching is seen more as a back-up career; have no formal training in teaching; have a teaching requirement ranging from 200 to 400 hours of teaching during their PhD; take our course voluntarily

TSU design principles:

- **Practicality and efficiency** - we focus on teaching techniques specific to university-level science (e.g., teaching the nature of science and uncertainty, conceptual change, teaching in the lab), and we designed the assignments such that participants develop and refine their own teaching content and interventions and can directly use the result in their own teaching.
- **Flexibility** – the bulk of the course material is taught during a 5-week online course. This allows participants to schedule their studies around their PhD research.
- **Basis in evidence** - we built the course around evidence-based teaching concepts and strategies, knowing that such evidence is how our audience of scientists makes meaning and accepts new ideas (e.g., Hattie, 2009; Schneider & Preckel, 2017).
- **Conceptual change** – in the absence of formal training, instructors tend to teach as they were taught. This means many continue to use information-loaded, transmission-oriented lectures, even when there is growing evidence of the importance of active student involvement in effective learning. In order to make lasting changes in participants' approaches to and beliefs about effective teaching, they must first experience cognitive dissonance that the current prevalent mode of university teaching is inadequate.
- **Utility of recipes/structured teaching sequences** – anecdotally we know from experience that scientists appreciate protocols when learning to implement a pedagogical strategy. It seems that a set of definitive steps helps bring structure to the ambiguous realm of pedagogy and all its new and associated vocabulary.
- **Peer learning** – we recognize that learning, especially the learning of a personal skill such as teaching, is principally a social endeavor. We take the time to engender a cohort identity in our blended participants. We train them in how to offer satisfying and constructive review of one another's work. And peer feedback both on assignments and in response to participants' final reflections are framed as "critical peer" activities which yield valuable perspective and idea sharing.
- **Reflection** – lasting behavior change and updating of one's cognitive understanding occur best when a person realizes for him or herself the value and benefit of their new ways of being and thinking. We build reflection in to every stage of TSU:
    - In day one to realize the problems and challenges of current modes of university teaching,
    - at the ends of each weekly online assignment to reflect how the teaching strategy is (perhaps) different from what they have experienced and to think of how one would know if this new strategy was helpful to student learning

  - at the end of the blended course when participants share what went well or poorly in their concurrent teaching and how their thoughts about teaching may have changed

TSU learning outcomes:
Our goal for the participants in TSU is that they develop so called "pedagogical content knowledge" or "PCK." This means, they develop the ability to tailor their teaching to a specific topic and the developmental level of their students in a way that leads to higher student attainment.

After taking this course, students will be able to:
1. choose effective and suitable evidence-based teaching strategies in different teaching situations
2. determine and use their students' pre-existing knowledge in the design and delivery of their teaching
3. create and use models and analogies to structure their teaching and clarify complex topics
4. frame their teaching such that it activates and motivates students
5. teach in the lab or field using a range of student inquiry and in a way that better reflects the nature of science research

TSU formats:
- massive open online course (MOOC) on the platform Coursera (www.coursera.org/learn/teachingscience) which is open-access, cost free, and attracts participants from around the world; participants can purchase a $49 USD certificate of completion
- blended in-person and online course available to the science PhD students at our university and utilizing the platform OpenEdX; earns 2 ECTS

Both versions of the course involve a 5-week online component in which participants watch short instructional videos, use course readings and informational handouts, complete an online assignment, then peer review the assignments of others.

Additional to this in the blended course are two in-person, half-day sessions.
- The first takes place at the beginning of a semester and introduces participants to the course, the change that is needed in university science instruction, and to each other.
- The second takes place after the online portion, and at the end of a semester. Typically, participants in the blended course also do some teaching of their own during this semester, so in the second in-person session, participants share reflections about what new techniques they tried in their own teaching, how their teaching went generally, and how their thoughts about teaching have changed.

ANALOGY ANALYSIS

This paper focuses upon the work of the blended participants in the specific assignment on teaching with analogies. In this assignment, participants are asked to think about something they typically teach or need to teach and to develop an analogy/teaching intervention based upon the what they have learned in the corresponding module.

Research questions:

Overarching PhD research question:
How does a course on teaching science in higher education influence the pedagogical content knowledge and teaching orientation of science PhD students?

RQ for this paper:
To what extent is the FAR-guide useful and effective for future life science instructors to develop and reflect upon using analogies in their teaching?

"PLAN"

- involves participant assignment questions 1-4
- I'm interested to know:
  - What kind of science topics do participants choose? Micro, meso, macro-scopic; school or HE level
  - Do participants pick familiar, experience-based, and appropriate analogs? Mesoscopic, embodied, far (not near), low cognitive load, culturally relevant, not outdated
  - How well do **participants** map the analog to the science concept (i.e., identify matches where the analogy works and mismatches where it no longer works)? Are the mappings superficial or do they also describe functional or causal (higher order) relationships? Particularly, do participants identify as mismatches instances in which an embodied/mesoscopic leads to a teleological or anthropomorphic logic about the science concept?

"REFLECT UPON"

- involves participant assignment questions 5 and 6 as well as analogy-relevant reflection presentations and post-course survey responses
- target publication field is faculty development
- I'm interested to know:
  - How participants reflect on the role, advantages, and disadvantages of analogies in their teaching
  - What kind of student feedback participants anticipate collecting as evidence of the effect and impact of teaching with their analogies
  - What kind of new insights participants report about teaching with analogies

Data sources and quantities:

1. **Written course assignments and peer review responses** – data digitally collected through the course OpenEdX interface.
   - Fall 2018 = 12
   - Spring 2019 = 15
   - Fall 2019 = 14
   - Spring 2020 = 10

- Spring 2021 = 24 (in 2 sessions)
- TOTAL: N= 75 participants

2. **Pre-post course survey responses**
    - Same total as data source 1: N= 75 participants
    - Relevant question = What was your favorite (or most useful) teaching tip or tool from the course? and Why?

Methodology:

- Qualitative content analysis of written participant assignments
    - Q 1-4 = deductive categories
    - Q 5,6 = inductive categories, looking for patterns in participant open responses
- N = 75 science PhD students/participants in TSU

Analogy Assignment Structure and Coding Guidelines

From the FAR Guide – Step 1 = FOCUS:
- ***Do participants pick a science concept which is difficult, unfamiliar, and abstract?***
- ***What do the students already know about the concept?***

Relevant assignment prompt(s) from TSU:
The aim of this task is to develop an analogy to use in your teaching. It might help to refer to this week's videos and to K2P briefs 7 and 8.

1. Choose a science concept you teach which students find difficult. Describe the concept here.

Analysis Rubric Prompts (in Excel)
1. Discipline of the chosen science concept?
2 a,b. What is the scale of the chosen science concept?
3. What type is the chosen science concept?
4. How does the participant acknowledge or describe why the concept is difficult for students?
5. Is the science concept (at the level of complexity described by the participant) likely to first be encountered in school (primary, secondary education) or at university (tertiary/higher education)?

Definitions
- Here "scale" refers to dimensions of the science concept (time, range, speed, acceleration, weight, temperature) and whether those dimensions are perceptible, i.e., mesoscopic (not microscopic or macroscopic). We use Niebert and Gropengiesser's categories (2015) based on Vollmer's (1984) definitions of mesocopic dimensions:

Table 1. Dimensions and boundaries of the mesocosm (cf. Vollmer, 1984)

	Lower boundary	Upper boundary
Time	seconds (e.g. heartbeat)	decades (e.g. lifetime)
Range	millimetre (e.g. hair: 0.1 mm)	kilometre (e.g. daytrip: 30 km, horizon: 20 km)
Speed	$v = 0$ (e.g. rest)	$v = 10$ m/s (e.g. runner and preying bird)
Acceleration	$a = 0$ (e.g. steady motion)	$a = 10$ m/s^2 (runner and free fall)
Weight	gram (e.g. ping-pong ball)	ton (e.g. tree, animal and rock)
Temperature	0°C (e.g. freezing point)	100°C (e.g. boiling of water)

Significance
- We believe one of the things that makes science difficult to learn for students is that many of its concepts are beyond humans' ability to directly perceive and/or experience. We know from the concept of embodied cognition, that bodily perception and interaction is a fundamental channel thorough which humans learn and make meaning.
- PCK elements in question = identifying what is difficult for students to learn in a particular subject, considering student prior knowledge when designing teaching ideas

Coding guidelines
1. Discipline – select one or more of the following (as many as are relevant):
- life science (biology, medicine)
- physical science (chemistry, physics, earth science, some geography)
- lab technique
- research method/process of science, statistics, modelling

- mathematics
- programming, computer science
- other

2. Scale – categorize the science concept as:
    a. Broad: (choose one if possible)
    - microscopic = smaller than the values listed above in Vollmer 1984's chart
    - mesoscopic
    - macroscopic = greater than the values listed above in Vollmer 1984's chart

    b. Detailed: (choose as many as relevant)
    - atomic
    - molecular
    - cellular
    - tissue/organ
    - organism
    - population/community
    - ecosystem
    - global
    - solar system/universe
    - theoretical/methodology-based
    - other

3. Type of science concept – use the following categories:
- physical structure
- physical process
- abstract (non-physical) structure
- abstract (non-physical) process

- Coding rule 1: If the science concept can be called a process, then that selection is favored (most processes also involve descriptions of structures, so selecting "structure" means ONLY a structure is described.)
- Coding rule 2: functions should be categorized as “processes”.

4. Consideration of student prior knowledge
- Select one: Addressed or not addressed

5. Secondary or tertiary? Is the science concept (at the level of complexity described by the participant) likely to first be encountered in school (primary, secondary education) or at university (tertiary/higher education)?
- Our decision-making basis here is communicative validation (Petra-Sara)

From the FAR Guide – Step 1 = FOCUS:

- ***Is the analog something your students are familiar with?***

Relevant assignment prompt(s) from TSU:
Participant Q2. Choose a suitable experience-based source domain (analog/object of comparison) for your analogy. Be sure the source domain is familiar to your students. Describe your analogy in the format: TARGET CONCEPT is SOURCE DOMAIN (e.g., PROTEIN SYNTHESIS is BUILDING A HOUSE.)

Participant Q3. Describe why this source domain will be familiar to your students.

I wonder
…how well will participants choose analogs that are familiar enough to help students make connections to prior knowledge and which harness the power of embodied cognition to connect to bodily learning and imagining.

Definitions

- The range of analogs deemed "familiar" runs from a typical thing or experience from everyday life to something one's students will have experienced themselves.

Significance

- A key theme in TSU is thinking about and planning teaching that considers the students' perspective. Are participants able here to think from the vantage point of their students' lives and experiences by picking analogs that are from **students'** everyday surroundings and exchanges? truly intercultural? current or at least not prohibitively old-fashioned? Things that **students** can and do experience?
- We are also interested to see if participants focus their rationalization of analog choice by focusing more on its familiarity or experience-basis. This could indicate their understanding of the role of bodily experience in learning. For reference, the following elements of embodied cognition were discussed in the course videos:
    - Everything we understand, we relate to some direct, bodily, or cultural experience
    - Embodied conceptions arise from perception, bodily movement and experience with the physical and social environment. – schemata, basic level concepts
    - ---imagination bridges these to---
    - Abstract conceptions for concepts which cannot be experienced directly, we need to think imaginatively to understand (climate change, carbon cycle, cell division, neurobiology)
- PCK element in question = choosing analogs which are familiar to students and experience-based (i.e., not adding to the cognitive load of the teaching segment by using an analog which also needs learning)

Coding prompts and guidelines
1. **Condition** (of the analog) – Here we want to connect to the study by Curtis & Reigeluth (1984) which looked at the condition of analogies in science text books. We therefore use their categories:

- concrete physical structure
- concrete physical process
- abstract (non-physical) structure
- abstract (non-physical) process
- not sure

- **Coding rule**: select only one of the above. Choosing "process" likely implies structure as well, but only choose process.

2. **Cognitive load** (of the analog) – Here we want to check that the analog does not require additional teaching before it is familiar and known to students and can therefore be used in the analogy. We look at two sets of criteria:

First – focus on the analog itself. **Coding rule**: only pick one of these four options.
- STRUCTURE (OBJECT) that requires NO additional teaching given the learning objective
- STRUCTURE (OBJECT) that REQUIRES additional teaching given the learning objective
- PROCESS (EVENT) that requires NO additional teaching given the learning objective
- PROCESS (EVENT) that REQUIRES additional teaching given the learning objective

- There is an additional column for "clarification" if necessary. Just type in notes here.

Second – focus on the description of the analog. This dichotomous choice is meant to indicate simplicity/complexity. **Coding rule**: only pick one of these two options.
- analog has NO particular situational description (conditions for its function)
- analog has a particular situational description (conditions for its function)

3. **Familiar 1**: Ideally the analog is familiar to students. In theory, when the analog is grounded in the mesocosm, it has a greater chance of being familiar.

Coding rule: Pick the single best fit of the following levels:
- Microscopic
- Functionally microscopic
- Mesoscopic
- Macroscopic
- Theoretical/methodological

4. **Familiar 2**: Ideally the analog represents something from the "everyday life" of students. In theory this would make the analog more likely to be familiar.

Coding rule: Pick one of the following:
- requires students to REMEMBER something MOST of them have experienced
- requires students to IMAGINE an experience which is realistically from everyday life
- requires students to IMAGINE an experience which is NOT realistically from everyday life

5. **Experience-based**: Ideally the analog involves bodily interaction with one's physical or cultural environment.

Coding rule: Pick as many of the following as relevant:
- involves bodily interaction with physical environment
- involves bodily interaction with cultural environment
- does not involve either of these
- other/unsure

6. Appropriate: Ideally the analog is generally applicable across ages, time, and cultures.
Coding rule: pick one of the following:
- intercultural?
- culturally specific – other cultures might not relate?

Coding rule: pick one of the following:
- current?
- Dated?

7. **Explanation of student prior knowledge of the** analog – what is the focus of participants' rational for student familiarity in question 3?

Coding rule: Pick as many as relevant:
- Specifies students' relevant knowledge
- Specifies students' relevant experience
- General knowledge
- General experience

- "Noteworthy text" = make a note if something grabs your attention as a particularly good explanation or showing good insight (for use as example text later)

8. **Analog complexity** – another indicator of cognitive load. Does the analog involve multiple comparison/are there multiple analogs? Or just a single, simple analog/comparison?

Coding rule: Pick one:
- one comparison
- Multiple comparisons
- other

From the FAR Guide – Step 2 = ACTION:
- ***Likes – Discuss the features of the analog and the science concept. Draw similarities between them.***
- ***Unlikes – Discuss where the analog is unlike the science concepts.***

Relevant assignment prompt(s) from TSU:
Participant Q4. Describe at least three ways the analog and science concept of your analogy match. And identify at least two shortcomings (where the analogy no longer works.)

I wonder
…if the guidance we gave in the module based on embodied cognition and the FAR guide resulted in analogies that meet the criteria for effectiveness established in the research community:
- Genter
- near/far research from psychology/educational psychology – Vendetti, Holyoak, Halpern, Hansen, Riefer, Hammadou

…if participants (or their peers) recognize the potential misconceptions that may arise from their analogy, especially those relating to:
- anthropomorphism, goal-directedness, teleology, teleonomy

Definitions
- mapping = comparing features of the analog and science concept
- match = a mapped element that works, i.e., is true and accurate
- mismatch = a mapped element that does not work, i.e., is false or inaccurate

Significance
- The education research community generally agrees that analogies *can* be effective tools for learning about abstract, complex concepts, BUT that they can also be used poorly and lead to student misconceptions. The success of a teaching and learning session with an analogy depends on the quality and thoroughness of mapping between the science concept and the analog. Effective mapping looks like:
    - Coverage of enough surface likenesses, structural elements to introduce and help establish the analogy
    - A focus on functional relationships and processes to encourage deeper thinking
    - Discussion of where the mappings do not match/where the analogy no longer works

Coding prompts and guidelines
1. Analysis of TYPES OF MAPPING

Background: We again want to compare our results with the work of Curtis & Riegeluth, 1984, who analyzed written analogies in 26 science textbooks - elementary to post-secondary, found 216 analogies, and categorized them by analogical relationship:

- structural relationship (same general physical appearance or similarly constructed - a cell is like a room)
- functional relationship (what the topic does, similar functions - feedback works like a building thermostat)

- structural-functional relationship (combines the two - a cell is a factory, office is the nucleus, and it controls…etc.)

(Their findings: 25% structural, 70% functional, 5% s-f.)

We also want to compare our findings with the mapping principles (of good analogies) according to Genter's Structure Mapping Theory, 1983. To summarize, her critical points are:

- We should map **relationships between** objects rather than **attributes of** objects.
    - Attributes of objects, e.g., x is large, y is large: mappings of only attributes means the analogy is actually just a similarity, an example.
    - Relationships between objects, e.g., x and y collide, y strikes z, x and y collide causing y to strike z: mapping at this level makes an analogy an analogy.
- Mapping can indicate lower or higher-order relations, and more effective analogies involve higher-order relations: causal, mathematical, functional > superficial
    - e.g., First order:
        - x and y collide
        - y and z strike
    - e.g., second order:
        - x and y collide causing y to strike z
- The **type** of mismatch identified (in other words, the **selectivity** of the mapping) is important. "Only certain kinds of mismatches count for or against analogies" (Gentner, 1983, p156)
    - e.g., batteries and reservoirs both tend to be cylindrical – irrelevant
    - batteries and reservoirs both tend to store potential energy – bingo!

Finally, we want to look to see where/if participants recognize what I am calling so far, "problematic personification". Here's the background: TSU stresses the importance of analogs being familiar and experience-based. This naturally leads to analogs which depict human activities, which most often include elements of goal-directed behavior or goal-oriented design, making conscious choices, having and acting upon a goal/wish/desire. If these elements get mapped to inanimate/non-living objects and processes or non-human species, there is a strong risk of applying teleological, teleonomic or anthropomorphic thinking incorrectly to the science concept. And while there is evidence that such thinking can be helpful in school children, it is not in line with the content expertise appropriate for content specialization at the university level. Some definitions and helpful examples:

- teleology = "the intuition that an intentional agent has designed a structure for a particular goal or function" (Stern *et al*., 2018, p. 2; Mayr, 1961)
    - Teleologic thinking would answer the question, "why?" or "what aim?" with an answer that begins with, "in order to…".
    - Teleology is distinct from anthropomorphic thinking as "it does not require attribution of sentience or agency. Instead, a goal, purpose or function could be seen as the cause of an event without intentional goal-oriented actions." (Betz *et al.*, 2019, p. 2)
    - Problematic examples:
        - birds have wings in order to fly
        - many species have camouflage in order to evade predators
        - cells have a full set of DNA so they can produce any necessary proteins
        - individuals of a species adapt and change to fit their environment (this last example is from Stern *et al*., 2018).
        - In these cases, the statement implies agency – the ability to act intentionally

        in order to fulfill a particular goal. Not only are these explanations scientifically inaccurate, but as they are satisfying answers to school children, then the true mechanism behind why a trait exists or why something functions as it does is left unexplored.
    - In contrast, non-problematic examples:
        - airplanes have wings in order to fly,
        - humans wear clothes in order to protect against the sun and cold.
        - In these cases, airplanes were intentionally and intelligently designed with a purpose in mind, and humans do exhibit goal-directed behavior through their conscious choices.
    - To complicate things a bit – there are legitimate and illegitimate teleological explanations. "Evolutionary explanations based on natural selection are inherently teleological in the sense that the advantage that a trait confers to its bearers explains its presence in the particular population." (Kampourakis & Niebert, 2018) To distinguish this "legitimate" teleology, the term "teleonomy" was coined.

- Teleonomy = "the quality of apparent purposefulness of structure or function in living organisms due to evolutionary adaptation" Merriam-Webster.com – but first coined by Pittendrigh (1958, p. 394).
    - Teleonomic thinking would answer the question "what for?" and refer specifically to the shaping of something through evolution and adaptation.
    - Examples: "The muscle is connected to the bone to move it." (Kampourakis & Niebert, 2018, p. 4)

- Anthropomorphism. Anthropomorphic thinking = applying human properties (characteristics, qualities, behaviors) to non-human or inanimate objects (Stern *et al*., 2018; Betz *et al.*, 2019)
    - Scientists consider anthropomorphic explanations to be unscientific, often teleological, to have problems with causality, and to lead us to include unevidenced and unnecessary external forces in our explanations (McGellin *et al.,* 2021)

2. Analysis of WHOLE ANALOGY STRUCTURE - Nearness and Farness
- Mapping principles of the Structure mapping theory (Gentner, 1983)
    - Analog and target should share fundamental characteristics, BUT, caution! – more shared characteristics is not necessarily better - analogies do NOT improve with greater overlap
    - Analog and target should belong to different systems – come from unfamiliar systems
    - The amount of overlap between domains (analog and science concept, in our case) has been used to characterize an analogy along a continuum from "near" to "far".
- NEAR: Analogies in which the analog and science concept have clear parallel structural similarities and belong to the same or similar system are called "near analogies" and can lead to overgeneralizations about the similarity of the science concept to the analog and misconceptions (Gentner, 1983; Halpern, Hansen, & Riefer, 1990). Near analogies tend not to cross domains: process-type analog maps to a process-type science concept; recipe to recipe, container to container
    - For example, reproduction in bacteria is like reproduction in humans (both are in the system, reproduction)

- FAR: opposite of near: analog and science concept come from different systems and share few surface similarities. Mappings are more likely to be analogical and require more critical thinking. Far analogies are more likely to cross domains.
    - For example, a cell is like a factory (very different systems, no surface similarities but many functionally analogous features)

Coding rules:

ANALYSIS OF TYPES OF MAPPING: We will use a combination of categories representing the work of Curtis & Riegeluth and Genter plus new categories to try to detect anthropomorphic or teleological elements. All categories will be applied twice – once for the likes/matches identified and once for the unlikes/mismatches.

To the extent possible, participants' answers have been additionally labelled L1, L2, etc. for the likes, and U1, U2, etc. for the dislikes. Sometimes this was not possible, as the answer text did not clearly outline likes and dislikes. Some participants included mappings in their answers to prompt 2 (column D). Be sure to consider also consider the labelled mappings there.

The number of likes and dislikes mapped have already been counted.

1. Consider each of the participant's mappings individually. Categorize it as one of these:

- Structural: same general physical appearance, surface likenesses, or similarly constructed; (also counting here = Static: not changing in the moment of description)
    - e.g., a cell is like a room
    - A.k.a. – descriptive mapping, feature-based mapping

or

- Functional: what the topic does, dynamic functions, processes, similar functions; (also counting here = Dynamic: changing (or able to change) in the moment of description)
    - e.g., feedback works like a building thermostat
    - A.k.a. – explanatory mappings, relationship-based mapping
    - Selecting functional likely includes structural concepts as well. In this case, we prioritize the selection of functional.

or

- Unsure, other (or poorly written)

Record HOW MANY mappings in that participant's assignment that fall into each category and also note WHICH mapping belongs in each category.

2. Then decide additionally if the mapping shows causality or is irrelevant (select as many as necessary):

- Causal: describes a relationship in which one feature leads to/influences another
    - e.g., x and y collide causing y to strike
- Irrelevant: describes something unimportant to the learning goal of the analogy

Record HOW MANY mappings in that participant's assignment that fall into each category and also note WHICH mapping belongs in each category.

3. Determine if any of the mappings show teleological, teleonomic, or anthropomorphic thinking or participant awareness of teleological, teleonomic, or anthropomorphic thinking (see descriptions/definitions above).

Specific indicators include:

- Teleonomic thinking: NOT problematic.

- Teleological thinking: inferring that something has been designed a structure for a particular goal or function
    - Look for: "so that", "in order to", "for (the purpose of)"

- Anthropomorphic thinking: applying human properties (characteristics, qualities, behaviors) to non-human or inanimate objects. Especially important here is goal-directed or intentional behavior.
    - Look for: a non-human or inanimate object paired with an ACTIVE VOICE VERB such as "moves", "chooses", "takes longer to.." + a clear context showing the action is intentional, choice-based

In other words, are non-living or non-human objects given living or human attributes, abilities, or behaviors in the analogy? Does the participant recognize this?

- Is this an issue in this analogy?
    - Enter a 1 if yes, leave blank if no.
- WHICH mapping or text show the problem?
    - List the mappings (L1, U2, etc.) that show awareness.
- WHICH mapping or text show the awareness of the problem?
    - List the mappings (L1, U2, etc.) that show awareness.

ANALYSIS OF OVERALL ANALOGY STRUCTURE – Nearness and Farness

Consider the whole analogy and determine if the analog and science concept are:

- NOT an analogy but rather a SIMILARITY, EXAMPLE, or ACTIVITY
- "Near" = come from same or similar system (e.g., immune function)
- "Far" = come from different/unsimilar systems (e.g., cell and urban architecture)

Pick only one category, make a "1" in the appropriate column.

PART TWO OF THE ANALOGIES ANALYSIS:

"REFLECT UPON"
- involves participant assignment questions 5 and 6 as well as post-course survey responses
- I'm interested to know:
    - How participants reflect upon on the roles, advantages, and disadvantages of analogies in their teaching or in their own learning as a student
    - What kind of new insights participants report about teaching with analogies
    - What kind of student feedback participants anticipate collecting as evidence of the effect and impact of teaching with their analogies

From the FAR Guide – Step 3 = REFLECTION:
- ***Was the analogy clear and useful, or confusing? Did it achieve your planned outcomes?***

Relevant assignment prompt(s) from TSU:
5. Reflection - How is the teaching you have described in this assignment different from how you usually teach or how you were taught as a student?

I wonder
- Have the participants developed a new competence or at least had a new experience in thinking about or designing their analogies?
- How did the participants experience engaging with analogies in this assignment? – as a student? As a teacher?
- What do participants see as the roles, advantages, and disadvantages of analogies?

Significance
- PCK elements in question
    - an awareness of the roles analogies can play in teaching and learning, especially when dealing with complex, micro- or macroscopic science concepts at the university level
    - pedagogical reasoning (or applied PCK in practice (Loughran, 2019)) - which can be understood as teachers being able to articulate their reasons for using particular pedagogical techniques.

Coding guidelines
- Pull key statements from the participants' text in three categories:
    - Own experiences with analogies as a student
    - Experiences with analogies as a teacher
    - General statements on analogies – Place statements here when:
        - unclear whether the experience/thought is from participants' experiences as a student or as a teacher
        - general thought or statement on the roles, advantages, disadvantages of analogies in teaching and learning
        - comment on something new participant learned in TSU
- When subsequent participant text parallels existing code, simply mark a "1" in the column of that code (frequency of the code is tabulated at the bottom of the column automatically)

From the FAR Guide – Step 3 = REFLECTION:
- ***Was the analogy clear and useful, or confusing? Did it achieve your planned outcomes?***

Relevant assignment prompt(s) from TSU:
Participant Q6. Reflection - Student learning - How would you know if this teaching intervention will lead to an improved good learning outcome for your students?

I wonder
- What kind of student feedback participants anticipate collecting as evidence of the effect and impact of teaching with their analogies? Do they focus on student understanding of the science concept or the analogy (or both)?
- How do participants refer to training materials in their answers to this question?

In the particular context of this analogy assignment, reflecting on own understanding of the analogy could involve:
- looking for where the analogy works (mapping of matches between analog and science concept)
- looking for where the analogy fails (mapping of mismatches between analog and science concept)
- extending the analogy further by making new connections/mappings to the science concept
- improving the analogy
- replacing the analogy with students' own version

Coding prompts and guidelines
INDUCTIVE coding
- Pull key statements from the participants' text in two categories:
  - Descriptions of what students or instructors would do/be able to do.
  - References to the training materials.
- When subsequent participant text parallels existing code, simply mark a "1" in the column of that code (frequency of the code is tabulated at the bottom of the column automatically)

REFERENCES IN CODING MANUAL

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