Exploring Cross-disciplinary Synergies in Teaching the Discourses of Physics and Chemistry in a 1st year Content-and-language-integrated Syllabus Module

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UBC Vantage College Speaker Series Event, May 3, 2021

Overview

1. Context: Academic English Program (AEP) at Vantage College (VC)

   VANT140 (Science): Content-integrated language course linked to courses in physics, chemistry, mathematics, computer science & earth & ocean science

2. New module for teaching a physics problem/solution genre

   Wucheng

3. Focal genre in Chemistry: explaining molecular reactivity using L Theory

   Anka

exploratory

Aims for Syllabus Devel

- Emphasizing core course aims: supporti variation:
  - between speech & writing (well-known a
  - among students in key *disciplinary* competencies (le
- Improving explicitness of syllabus (Hughes et al, 2017) by reducing complexity (& fatigue) across five linked sciences:
  - More stable nexus and point of departure across these disciplines
  - Expand syllabus development in physics literacy teaching to chemistry

IMPLICATIONS
- data-driven learning
- multimodality & individual differences

Vantage College Student Profile

- International (24+ countries of origin)
- Recent high school graduate (18~19 yrs)
- High academic achievers who score slightly below university language admission requirements

Vantage One Science Stream, UBC-V (41-42 credits total)

	Term 1	Term 2	Summer Term
	Chemistry Math Physics	Chemistry Math Physics EOSC or CompSci	Physics Computer Science Chemistry
A E P	**Academic writing (LLED 200)**	**Writing Research (LLED 201)**	
	Integrated Language & Content Course (VANT 140)		
	Multidisciplinary Research Projects & Capstone Conference		

Language as a functional resource in context: Theory

The three functions of language in context; collectively, a register:

- Social positioning
- Ideation: content & logic
- Information organization

Language includes

- semantics (three functions/register) & grammar (wording)
- wording *realizes* the functional profile text (its register)

Map of Academic Genres and Registers

Functions	Wording			
	Text-level	Phase-level	Clause-level	Word-level
Ideation (content & logic)				
Social positioning				
Information organization				

Typical patterns – described probabilistically

Example: heuristic for exploring drafts of expository writing

Adapted from
Humphries et al, 2010

	A. Text Level The whole text	B. Section Level Text stages, sections & paragraphs	C. Clause and Word Levels Sentences, clauses, groups, phrases and words
1. Content Function These questions focus on the functions of representing and logical relations; that is, on what's going on, with whom or what, and under what circumstances, and the logical connections between ideas. Writers focus on the content function in order to build well-reasoned valued knowledge of a discipline.	• Do the beginning, middle, and end stages of the text build knowledge relevant to the topic and purpose? • Do logical relations set up between stages express the appropriate kinds of reasoning for this text (e.g., explanation, description, procedure, etc.)?	• Does the information in the paragraphs progress from general to specific? • Is there an initial sentence to preview the ideas and orientations in this section for the reader? • Are ideas within each paragraph or section logically ordered (e.g., by time, cause, consequence, comparison, or a sensible mix of logics)?	• Are concepts and other entities appropriately represented, using a sensible level of abstraction or generalization? • Are experiences (material, verbal, mental actions) and associated circumstances appropriately represented? • Are causal and other logical relations appropriately presented in verbs, nouns, and circumstances?
2. Interpersonal Function These questions focus on how writers position themselves in relation to their claims and to the reader. Writers work through interpersonal choices to convince readers of the writer's claims by fair and reliable means.	• Does the text build the author's points and positions across its stages (e.g., reinforce & amplify)? • Does the writer demonstrate familiarity with disciplinary expectations?	• In each stage of the text, does the writer direct the argument and the reader in a preferred direction? • Are a range of perspectives introduced?	• Are claims appropriately weighed, with well-supported claims presented confidently, and more speculative claims hedged? • Does the writer position themselves effectively in relation to the reader? • Are key claims appropriately supported with citations? • Is the level of formality of the vocabulary appropriate?
3. Organizational Function These questions focus on how writers organize the written message to facilitate its interpretation by readers. Often after the content and interpersonal functions are set, writers revise the information order considering what is background, known and new information *for the reader*.	• Does the title preview key ideas and orientations presented in the text? • Are headings and subheadings used to signal the organization of longer texts? • Are all in-text citations properly referenced at the end of the text?	• Does the information flow well within paragraphs and text subsections? • Is there an initial sentence to preview the ideas and orientations in this section for the reader? • Are specific ideas easy to track in the text through cohesive resources, such as pronouns, repetition, synonyms? • Are changes in logic signalled using appropriate phrases?	• Does the subject of each clause contain information that is known or expected to be known to the reader? • Is information that is new to the reader introduced at the end of sentences?

VANT140 Science: Pre-pandemic

Discipline	Language Focus	Technology
Physics	Organizing solutions into stages, signaling shifts	Canvas/PPT
Mathematics	Stress and intonation in spoken solutions	CLAS
Chemistry	Academic and technical vocabulary in labs and lab reports	Concordancer
Earth Ocean Science / Computer Science	Paraphrasing: paragraph-level	Canvas/Word

Instructional Starting Points by Discipline

Functions	Wording			
	Text-level	Phase-level	Clause-level	Word-level
Ideation (content & logic)	Physics	EOSc & Comp Sci		Chemistry
Social positioning				
Information organization		Math		

Holistic Perspective on Disciplinary Genres (but… complexity)

Functions	**Wording**			
	Text-level	Phase-level	Clause-level	Word-level
Ideation (content & logic)	Physics			
Social positioning				
Information organization				

Exit survey (2016): **Reflection by Applied Science student**

In the VANT140 classes that I took this term, I have properly learned all the scientific concepts in a better way, as I am able now to approach the problems from an aspect of language, which makes me comprehend the scientific wordings that are present. I used to approach the **mathematical, physical, and chemical problems** in a very narrow aspect, where I did not really understand the main purpose of the problems.

New Developmentally-relevant Nexus for Disciplinary Literacy

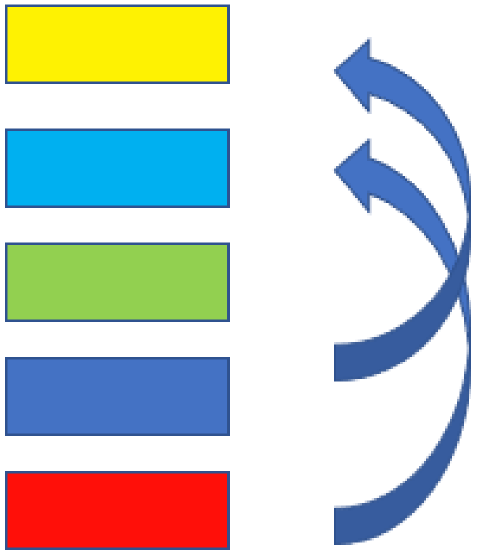
Speech-Writing Continuum

Variation in Relevant Competencies

Functions	Wording			
	Text-level	Phase-level	Clause-level	Word-level
Ideation (content & logic)	Physics	EOSc & Comp Sci		Chemistry
Social positioning				
Information organization		Math		

5-stage Approach to Solving Physics Problems

1. Interpret the problem
2. Model the problem
3. Plan a solution
4. Solve
5. Check/Interpret your answer



According to

- Physics 117 textbook, instructor Georg Rieger;
- experience of TA, course alumnus, Wucheng Zhang

Speech-Writing Continuum

- Procedural genre
- variation in info density and complexity

Relevant competencies

- Interpretive/qualitative
- Visual
- Mathematical

5-Stage Approach to Solving a Physics Problem

1. Interpret the problem
2. Model the problem
3. Plan a solution
4. Solve
5. Check/Interpret your answer

Speech-Writing Continuum

- Procedural genre
- variation in info density & complexity, recursiveness

Spoken group work

Bob: I think it is my job to plot the graph. (Graph of the Doctor and TARDIS)

Alice: This one is easy. We only have to check when he reaches TARDIS and check whether this time is shorter than 5s. Let's the check the kinematic equations. We have known $v_0 = 13m/s$, $a = -2m/s^2$ and $x = 30m$ and we want to know the time t. This equation works perfectly.

$$x = \frac{1}{2}at^2 + v_0 t$$

Plugging the number, we then have $30 = -t^2 + 13t$. With rearrangement we have a quadratic equation $t^2 - 13t + 30 = 0$. This one has two roots, $t = 3$ and $t = 10$.

Coral: Then we have two solutions? Dr. WHO is going to reach the TARDIS in 3s or 10s, isn't he? By the way, Alice, when solve the root of the equation, don't forget to add the units. It should be $t = 3s$ and $t = 10s$.

Bob: Yeah, you are right Coral. Two possible times is weird. Then doctor is possibly going to die or possibly going to be alive. Why we have two solutions? Does the problem give us sufficient information?

Coral: Let's pull our thought back a little bit and ignore the equation temporally. Let's think about the physics behind. Please notice that the air resistance only exists when the speed of doctor is not 0. That means the acceleration $a = -2m/s^2$ will be zero when doctor stops. However, the kinematic equation we used requires a constant, nonchanging acceleration.

Alice: Then can we still use this equation? If so, how can we know which solution is the realistic?

Coral: Yes can still use this equation because when doctor is still running the acceleration is still there. I think we probably only need the smaller one. The larger time seems to appear after the doctor first reaches TARDIS.

Bob: Yeah, now I know where the second time comes from. We draw the v-t diagram (v-t diagram). Since the area under the line is the displacement, A=30m and B-C=30m are the two possible cases. The left one is the case we are considering. The right one requires that the acceleration still exists even when doctor stops. In this case doctor first pass TARDIS then turns the direction later and runs back to TARDIS. This case should be ignored.

Alice: I see the time is actually 3s and doctor can leave in time. Great!

Written

Strategy and Analysis:

Graph of the Doctor and TARDIS

In this problem, the doctor is moving with constant acceleration. Our goal is to find out the time t when the doctor reaches TARDIS given the initial speed $v_0 = 13m/s$,
acceleration $a = -2m/s^2$ and
the distance to travel $x = 30m$.

Based on the known and unknown variables, we can apply the following kinematic equation

$$x = \frac{1}{2}at^2 + v_0 t$$

Then solve the time t.

Since it is a quadratic equation, we might have two roots. The physically meaningful roots should be positive and with non-negative velocity at that time t because the air resistance disappears when $v = 0$.

Solution:
Plugging in the number $v_0 = 13m/s$, $a = -2m/s^2$ and $x = 30m$ into
$x = \frac{1}{2}at^2 + v_0 t$,
we have $30 = -t^2 + 13t$.
With arrangement it turns out to be $t^2 - 13t + 30 = 0$ with two roots $t_1 = 3s$ and $t_2 = 10s$.

Both of the results are positive, however, at t_1, $v_1 = v_0 + at_1 = 7m/s > 0$
while at t_2, $v_2 = v_0 + at_2 = -7m/s < 0$.
Therefore, only the first root has a valid physics meaning, i.e. it takes the doctor 3s to get into TARDIS.

Significance:
The three seconds it takes the doctor to reach the TARDIS allow him to escape in time before this planet explodes. The other root, with negative speed at that moment, corresponds to the case in which the doctor first passes the TARDIS, then turns the direction and accelerates back to the TARDIS. This is, of course, unwise for our doctor and impossible in physics.

Pedagogical Procedure for Module for Writing a Solution Formally from Spoken Dialogue

e.g., Humphry et al, 2010

1. Explicit instruction
2. Joint construction
3. Independent construction

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Spoken and Written Variations of Physics Solutions

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Spoken: recursion and lower information density: HOW?

Variation in Speech and Writing: Information density
nb: meaning/wording articulation

Halliday, 1998

speech ↕ writing

1. We	used	this kinematic equation		because	the object	accelerates	at a constant rate
2. We	used	this kinematic equation	due to the object's constant acceleration.				
3. Our use of of this kinematic equation	stems from	the constant acceleration of the object.					
4. The motivation for the use of this kinematic equation linked to constant acceleration...							

+ Information + Density + Abstraction

Variation in Speech and Writing:
Abstraction in meaning/negotiability: types of processes

Verb/Process

speech	1. We	used	this kinematic equation		because	the object	accelerates	at a constant rate
speech	2. We	used	this kinematic equation	due to the object's constant acceleration.				
writing	3. Our use of of this kinematic equation	stems from	the constant acceleration of the object.					
writing	4. The motivation for the use of this kinematic equation linked to constant acceleration...							

Material processes

Relational (=) process

(no process)

Variation in Speech and Writing:
Information density: nominalization/downgrading

	GRAMMATICAL CATEGORIES	sentence							
	1st clause				conjunction / logical relator	2nd clause		
		Noun Group / Participant	Verb Group/ Process	Noun Gp / Participant	Adverbial/ Circumstance		Noun Gp / Participant	Verb Group/ Process	Adverbial/ Circumstance
speech	1.	We	used	this kinematic equation		because	the object	accelerates	at a constant rate
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writing	3.	Our use of of this kinematic equation	stems from	the constant acceleration of the object.					
writing	4.	The motivation for the use of this kinematic equation linked to constant acceleration...							

Processes into things:

Nominalization:

accelerate => acceleration

used => use

Variation in Speech and Writing: Information density: logical metaphor

	GRAMMATICAL CATEGORIES				sentence			
	1st clause				conjunction / logical relator	2nd clause		
	Noun Group / Participant	Verb Group/ Process	Noun Gp / Participant	Adverbial/ Circumstance		Noun Gp / Participant	Verb Group/ Process	Adverbial/ Circumstance
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Metaphors of causal logic:

because (conjunction)=>

due to (adverbial) =>

stems from (verb) =>

motivation (noun)

Groundwork for developments in educational technology

	GRAMMATICAL CATEGORIES				sentence			
	1st clause				conjunction / logical relator	2nd clause		
	Noun Group / Participant	Verb Group/ Process	Noun Gp / Participant	Adverbial/ Circumstance		Noun Gp / Participant	Verb Group/ Process	Adverbial/ Circumstance
...ch	1. We	used	this kinematic equation		because	the object	accelerates	at a constant rate
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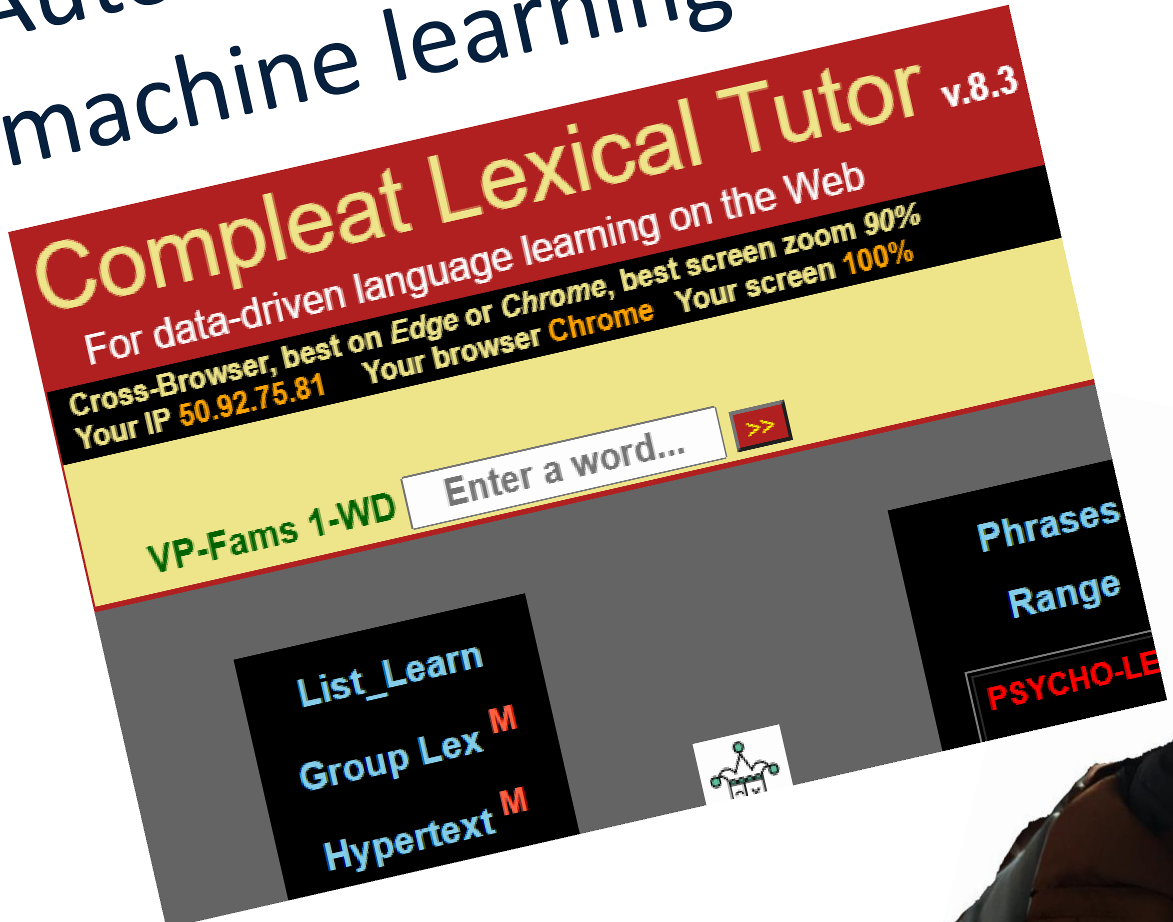
writing	3. Our use of this kinematic equation	...ems from	the constant acceleration of the object.					
	4. The motivation for the use of th... linke... acceleration...							

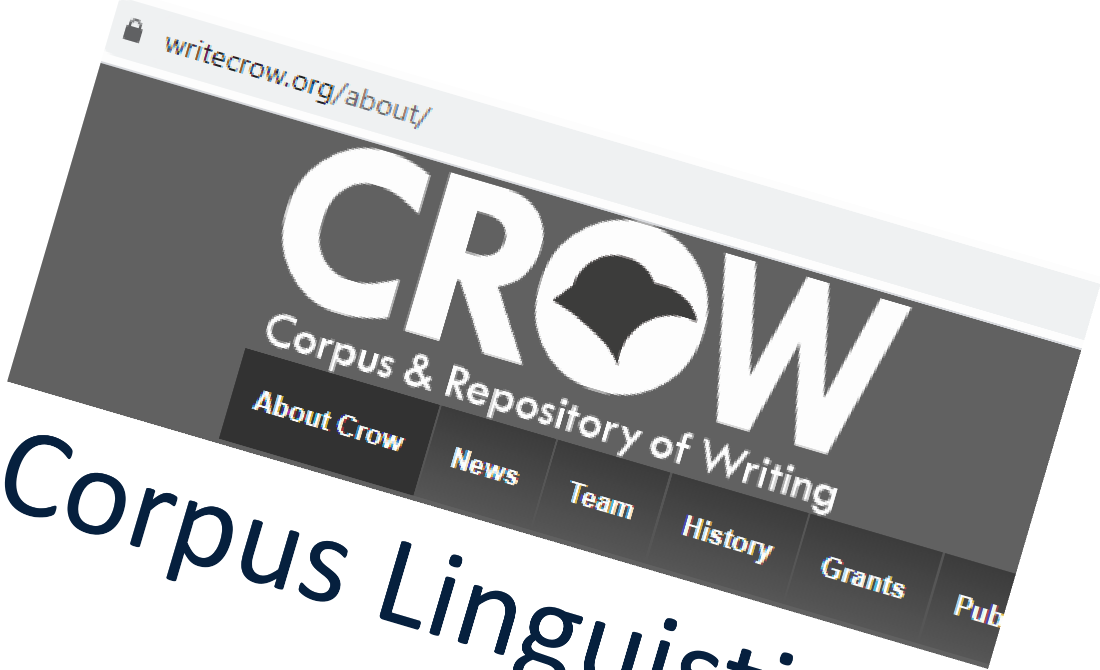
Nominal Density: **1**

Nominal Density: **2** (Ferreira, 2020)

Syllabus Development = Groundwork for eg data-driven disciplinary language teaching & learning

Automatic text analysis; machine learning tools

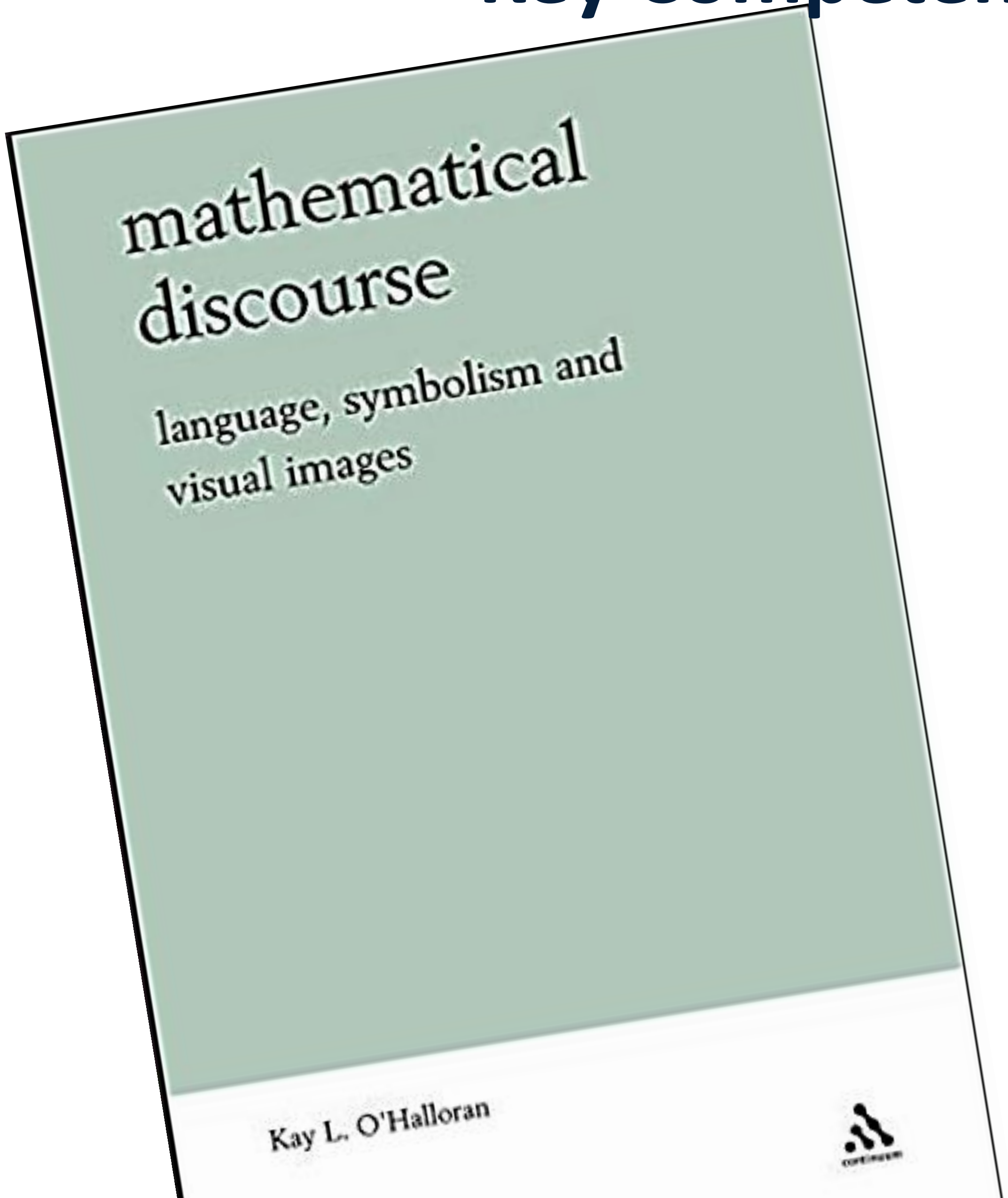




Corpus Linguistics

I've developed a code for analyzing levels of abstraction in texts

Key Competencies & Multimodality



Checking the kinematic equations,
we know $v_0 = 13m/s$, $a = -2m/s^2$ and $x = 30m$ and we want to know the time t.

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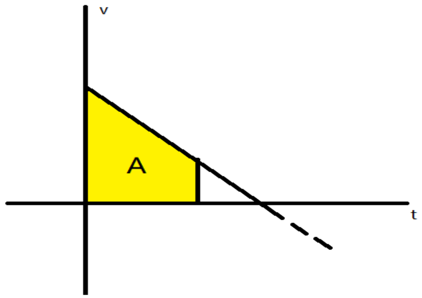
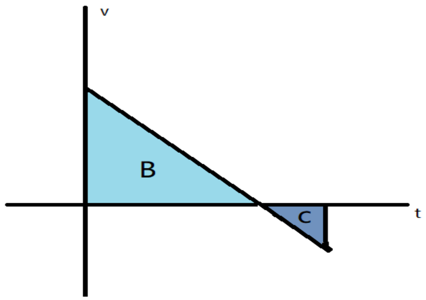
…

Let's draw a v-t diagram.





Key competencies: TASK

e.g., **Alice**

comes to a solution mathematically but too quickly & narrowly (gap in qualitative analysis: known pitfall)

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2. Model the problem
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Rationale for *Variation in Relevant Competencies for Solving Physics Problem*

Problem Solving in Physics
Students' Strength and Weakness

Meaning-making in Physics

Alice: good at math ⟺ Equations

Bob: good at visualizing ⟺ Graphs

Carol: good at qualitative analysis ⟺ Words

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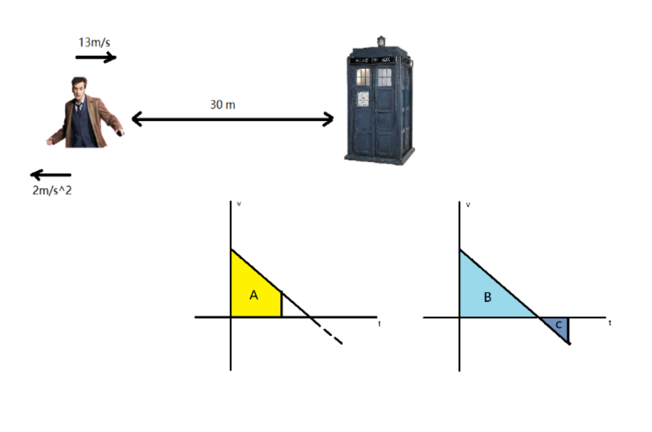

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$$x = \frac{1}{2}at^2 + v_0 t$$

Plugging the number, we then have $30 = -t^2 + 13t$. With rearrangement we have a quadratic equation $t^2 - 13t + 30 = 0$. This one has two roots, $t = 3$ and $t = 10$.

Coral: Then we have two solutions? Dr. WHO is going to reach the TARDIS in 3s or 10s, isn't he? By the way, Alice, when solve the root of the equation, don't forget to add the units. It should be $t = 3s$ and $t = 10s$.

Bob: Yeah, you are right Coral. Two possible times is weird. Then doctor is possibly going to die or possibly going to be alive. Why we have two solutions? Does the problem give us sufficient information?

Coral: Let's pull our thought back a little bit and ignore the equation temporally. Let's think about the physics behind. Please notice that the air resistance only exists when the speed of doctor is not 0. That means the acceleration $a = -2m/s^2$ will be zero when doctor stops. However, the kinematic equation we used requires a constant, nonchanging acceleration.

Alice: Then can we still use this equation? If so, how can we know which solution is the realistic?

Coral: Yes can still use this equation because when doctor is still running the acceleration is still there. I think we probably only need the smaller one. The larger time seems to appear after the doctor first reaches TARDIS.

Bob: Yeah, now I know where the second time comes from. We draw the v-t diagram (**v-t diagram**). Since the area under the line is the displacement, A=30m and B-C=30m are the two possible cases. The left one is the case we are considering. The right one requires that the acceleration still exists even when doctor stops. In this case doctor first pass TARDIS then turns the direction later and runs back to TARDIS. This case should be ignored.

Alice: I see the time is actually 3s and doctor can leave in time. Great!

5-Stage Approach to Solving a Physics Problem

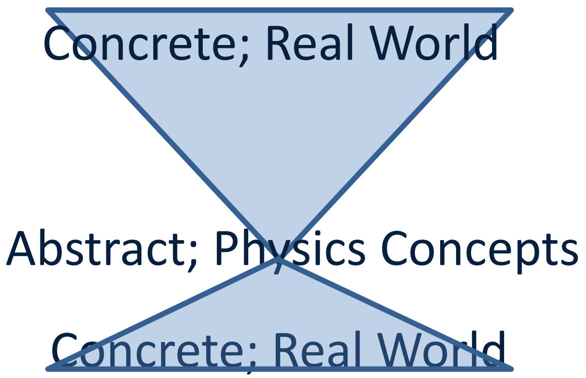
1. Interpret the problem
2. Model the problem
3. Plan a solution
4. Solve
5. Check/Interpret your answer

- Collaboration to solve the problem
- Nonlinear in staging
- Emphasis on the application of intuition

Rationale for *Variation in Relevant Competencies for Solving Physics Problem*

5-Stage Approach to Solving
a Physics Problem

1. Interpret the problem
2. Model the problem
3. Plan a solution
4. Solve
5. Check/Interpret your answer



visualization, qualitative analysis

visualization, math

visualization, qualitative analysis

e.g.

run, accelerate, reach X

↓

velocity/speed, acceleration and the displacement (physics assumption in required)

↓

run, accelerate, reach X

Applying (1) Speech-Writing Continuum to Chemistry

Physics Genre:

Physics solution procedure

5-stage approach

speech	1.	We	used	this kinematic equation		because	the object	accelerates	at a constant rate
	2.	We	used	this kinematic equation	due to the object's constant acceleration.				
writing	3.	Our use of of this kinematic equation	stems from	the constant acceleration of the object.					
	4.	The motivation for the use of this kinematic equation linked to constant acceleration...							

Chemistry Genre:

Factorial explanation based on figure

Phenomenon (Selected Answer)

Factor 1 (refer to figure)

Factor 2 "

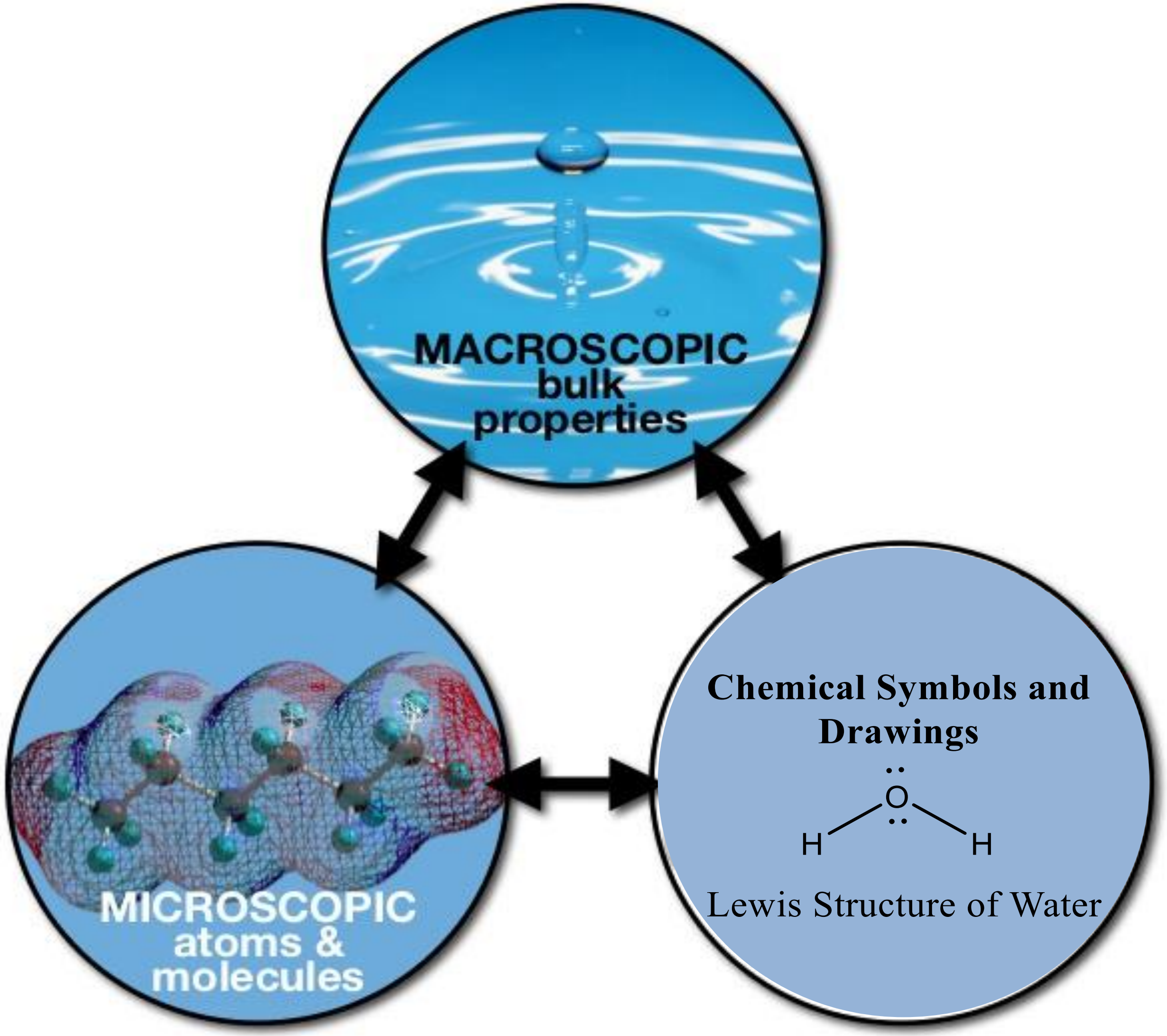
Factor 3 "

...

Key Task in 1st Year Chemistry

Students learn to draw molecules based on Lewis Theory.

The drawing contains significant information that helps explain macroscopic observations, such as reactivity.



Example Question

The nitrogen-oxygen (N-O) bond length in $[NO]^+$ is 106 pm and the N-O bond length in NO_2 is 124 pm.

Question 1: What is the N-O bond length in $[NO_2]^+$?

(A) 106 pm

(B) 124 pm

(C) 90 pm

(D) 140 pm

(E) 115 pm (E is the correct answer)

Question 2: Explain your answer

Written (Multimodal) Explanation

ANSWER:

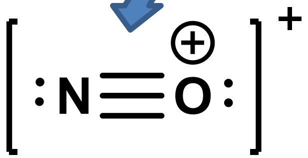
(A) 106 pm

(B) 124 pm

(C) 90 pm

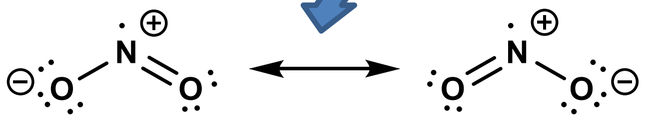
(D) 140 pm

(E) 115 pm



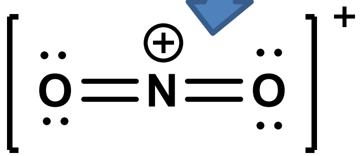
Bond length = 106 pm

The bond is a triple bond



Bond length = 124 pm

The N-O bond is between single and double bond



Bond length = ??

The N-O bond is a double bond

Option E is correct for the following *reasons*. [**nb** identify phenomenon to explain then list factors:]. Bond length decreases as bond goes from single to double to triple, with a triple bond being the shortest. The N-O bond length in $[NO_2]^+$ (with a double bond) is expected to be shorter than that of NO_2 (124 pm, with a bond between a single and double), but longer than that of $[NO]^+$ (106 pm, with a triple bond). The only option that fits both of these *criteria* is option (E) at 115 pm.

Dr. Anka Lekhi
on Relevant Competencies in Chemistry
(towards syllabus development…)

What might be some common strength/weakness profiles that students present when managing this chemistry task?

Thank you!

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