Middle School Students' Pathways of Learning About Water Flow

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Introduction

During the past decade, we have developed a learning progression (LP) for water in environmental systems that describes levels of achievement from informal force-dynamic to scientific model-based ways of understanding water moving through hydrologic systems (Table 1, Gunckel, Covitt, Salinas & Anderson, 2012).

Level of Achievement	Type of Account	Elements of Accounts		
		Structure & Systems	Scale	Principles
Level 4: Model-based accounts	Explanations of how & why water moves	Multiple, detailed & connected hydrologic systems	Connected across atomic-molecular through large scale	Invoke scientific principles (driving forces, constraining factors)
Level 3: Phenomen-ological (school science accounts)	Descriptions of what happens	Connected systems; visible & some hidden components	Spans micro to macro scale, some challenges linking scales	Address ordered events, named processes, & uses school rules
Levels 1&2: Force-dynamic accounts	Force-dynamic descriptions of actors fulfilling purposes	Visible, familiar components of hydrologic systems	Visible, macroscopic scale	Invoke actors' capacities & purposes as explanation

Table 1. Water systems learning progression

We've found most middle school students begin at level 2 (L2), and students who receive LP-based instruction are more likely to move to providing L3 responses (Gunckel, Covitt & Salinas, 2014). L3 represents a discourse of naming steps and processes involved in water movement. However, L3 does not involve using scientific principles (e.g., drivers such as gravity, or constraints such as topography or permeability) to explain how and why water moves.

Few students move to L4. Further, there are several ways to demonstrate L3 understanding – evident in different indicators used to code responses. Most L3 indicators reflect school science narratives (i.e., using school rules such as "rivers flow into lakes," or describing *what* happens without describing *how* or *why*).

L3, however, can also reflect problematic attempts to use scientific principles. For example, a problematic principle-based L3 response might name gravity as a driving force, but then describe water as moving upstream based on a map.

Indicator analysis can provide insights into learning pathways students may follow.
Which indicators are most common?
Can instruction impact types of responses (i.e., are students who experience more effective instruction more likely to provide principle-based responses)?

Such analyses can help us understand whether, to what extent, and how LP instruction may support learning.

Research Question

For students who demonstrated learning (moving from L2 to L3 or L4), what types of reasoning were evident in post responses, and how were those types related to teachers' LP instruction experience?

Design and Methods

We examined pre-post data (N=914) for students of 22 middle school teachers from 2 mountain west states who participated in a water education project. Teacher participation involved:
•4-day PD workshop
•enacting LP-based water instruction
Teacher and student participation is summarized in Table 2. Most year 1 comparison teachers were year 2 participants.

	2011-2012 Teachers (Students)	2012-2013 Teachers (Students)
Comparison	9 (211)	N/A
1st Year Implementers	10 (249)	10 (252)
2nd Year Implementers	N/A	7 (202)

Table 2. Teacher and student participants

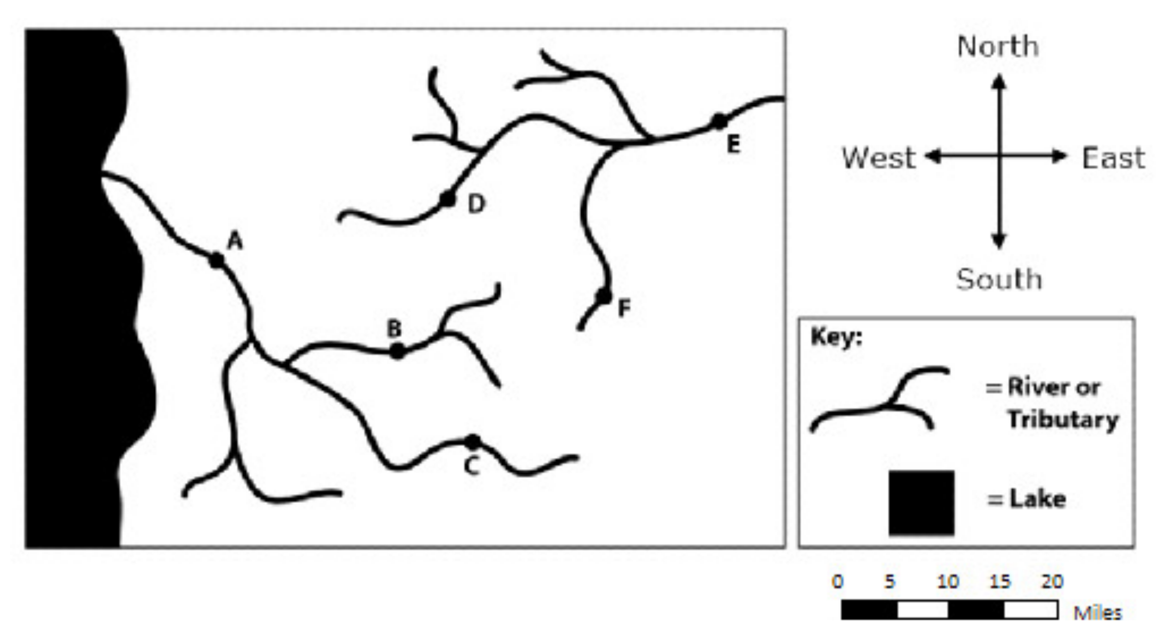


Figure 1. River Map Questions

Question 1: Can pollution in the river water at Town B get to Town C? Explain why or why not.
Question 2: Describe the direction water is flowing away from Town F. How do you know the water is flowing this direction?

Data were analyzed for change in level of achievement (Gunckel, Covitt, Salinas & Anderson, 2012). Coding involves identifying level indicators in responses (Table 3). Excellent weighted Cohen's Kappa IRR values were achieved for level coding (>0.8). We are working on indicator coding IRR.

To investigate students' learning pathways, we examined which L3 and L4 indicators were present in post responses.

Indicator	Question 1 Examples	Question 2 Examples
3.1 Describes direction of water flow.	No. Because the water is going toward A not C.	It would go north and then it would go east after it joined up with the other river. I just guessed but it was a very good guess.
3.2 Uses school rules (e.g., water flows from rivers to lakes) w/out attending to principles.	No. Because all small bodies of water always flow to bigger bodies of water such as the lake.	The water is flowing to the right of the picture away from Town F. Because Town E appears to be the main river everything is flowing into.
3.3. Correctly identifies upstream/downstream w/out identifying drivers.	No. Because the river can't flow downstream and then upstream.	N/A
3.4 Applies principles, but in problematic way.	Yes. Well it can depending on the elevation if Town B has a higher elevation than C it can.	South down to lower elevation until it evaporates or soaks into the ground. Water always flows to lower elevation and it can never flow to higher elevation due to gravity.
4.1 Uses driver of gravity and/ or constraint of topography to accurately explain water flow.	No. The water is flowing downhill to the lake, the water can't go up the hill due to the force of gravity.	The water is flowing north then east. They are different watersheds and they are seperated by ridges.

Table 3. Levels 3 and 4 indicators, with example responses

Results

We focus on the majority of students responding at L2 on the pretest. Then, we focus further on those providing L3 or L4 post responses (see Table 4).

Group	Total # of Students	Question 1		Question 2	
		# (%) who began at L2	# (%) moved to L3 or L4	# (%) who began at L2	# (%) moved to L3 or L4
Comparison	211	112 (53%)	5 (4%)	127 (60%)	12 (9%)
1st Year Implementers	501	300 (60%)	67 (22%)	346 (69%)	63 (18%)
2nd Year Implementers	202	125 (62%)	49 (39%)	139 (69%)	52 (37%)

Table 3. Number (percentage) of student who progress from L2

Results (Table 4) suggest students of teachers with more LP experience demonstrate greater learning. It appears that both initial LP PD, as well as experience implementing LP instruction contribute cumulatively to effectiveness in supporting student learning.

Figures 4 and 5 show percentages of students whose responses reflected each of the L3 or L4 indicators. Indicators are not mutually exclusive, so indicator percentage totals for each group can be >100%.

- Non-principle based L3 indicators, and particularly 3.1 and 3.2, are most frequent for all groups for both questions.
- Problematic principle-based indicator (3.4) and accurate principle-based indicator (4.1) become more common as teachers gain experience.
- Note problematic principle-based responses are more common than accurate principle-based responses, and, while indicators reflecting attention to principle increase with teacher experience, the frequency of non-principle-based indicators does not necessarily drop off.

Figure 4. Question 1 Indicators by Teacher Group

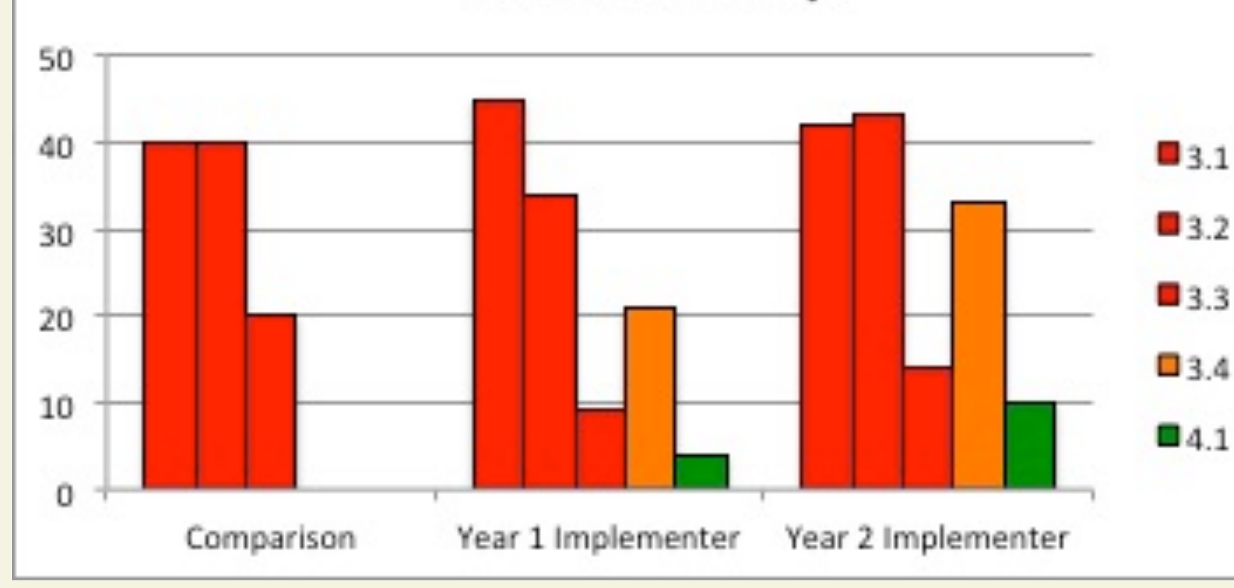
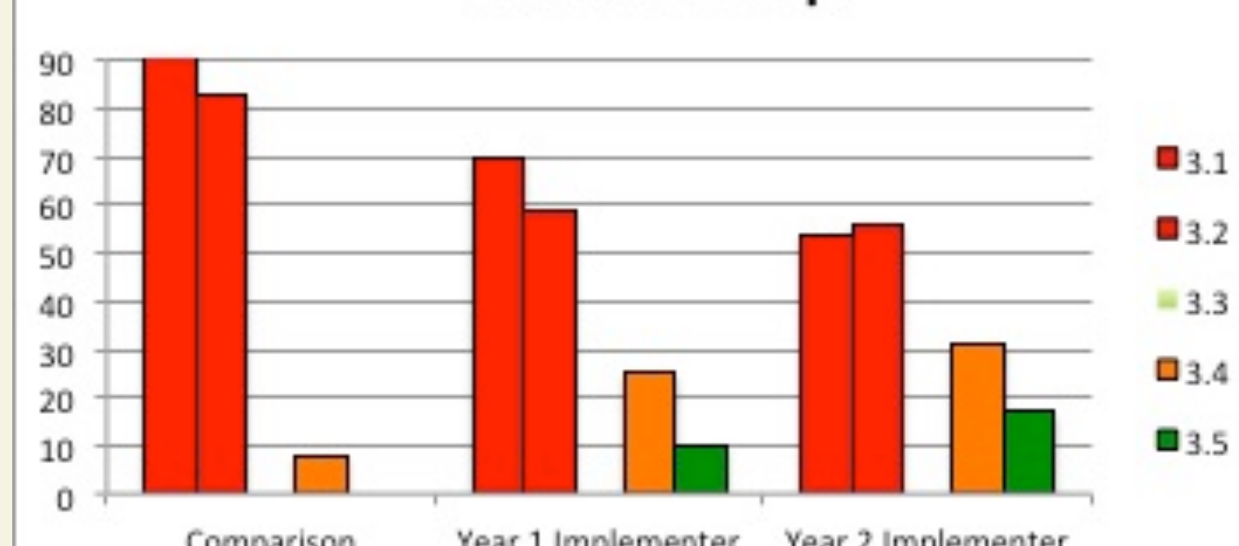


Figure 5. Question 2 Indicators by Teacher Group



Discussion and Implications

The result that both the problematic principle-based indicator (3.4) and the accurate principle-based indicator (4.1) become more common as teachers gain experience suggests that student learning can be influenced differentially by more or less effective LP instruction.

We infer from this that as teachers gain experience, they may place more instructional emphasis on students developing principle-based explanations.

The fact that non-principle-based indicators remain frequent even as principle-based indicators begin to appear, though, suggests that providing non-principle-based descriptions is a common learning pathway. This is not a bad thing; L3 represents reasoning that is more sophisticated than L2 accounts, and that is not necessarily inconsistent with L4, model-based reasoning.

Several implications include:

- Relatively few students move toward non-principle based L3 without LP-based instruction.
- Progress toward either problematic or accurate principle-based reasoning is *extremely rare* without LP-based instruction.
- Teachers may require several years to develop proficiency with LP instruction.

References

Gunckel, K., Covitt, B., Salinas, I., & Anderson, C. 2012. A Learning Progression for Water in Socio-Ecological Systems. *Journal of Research in Science Teaching, 49*(7), 843-868.

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