Use of Learning Maps as an Organizing Structure for Formative Assessment

Presentation at Maryland Assessment Research Center Conference

November 8, 2019

On the efficacy of formative assessment

EDUCATIONAL MEASUREMENT:
ISSUES AND PRACTICE

NCME national council on measurement in education

Educational Measurement: Issues and Practice
Winter 2011, Vol. 30, No. 4, pp. 28–37

Formative Assessment: A Meta-Analysis and a Call for Research

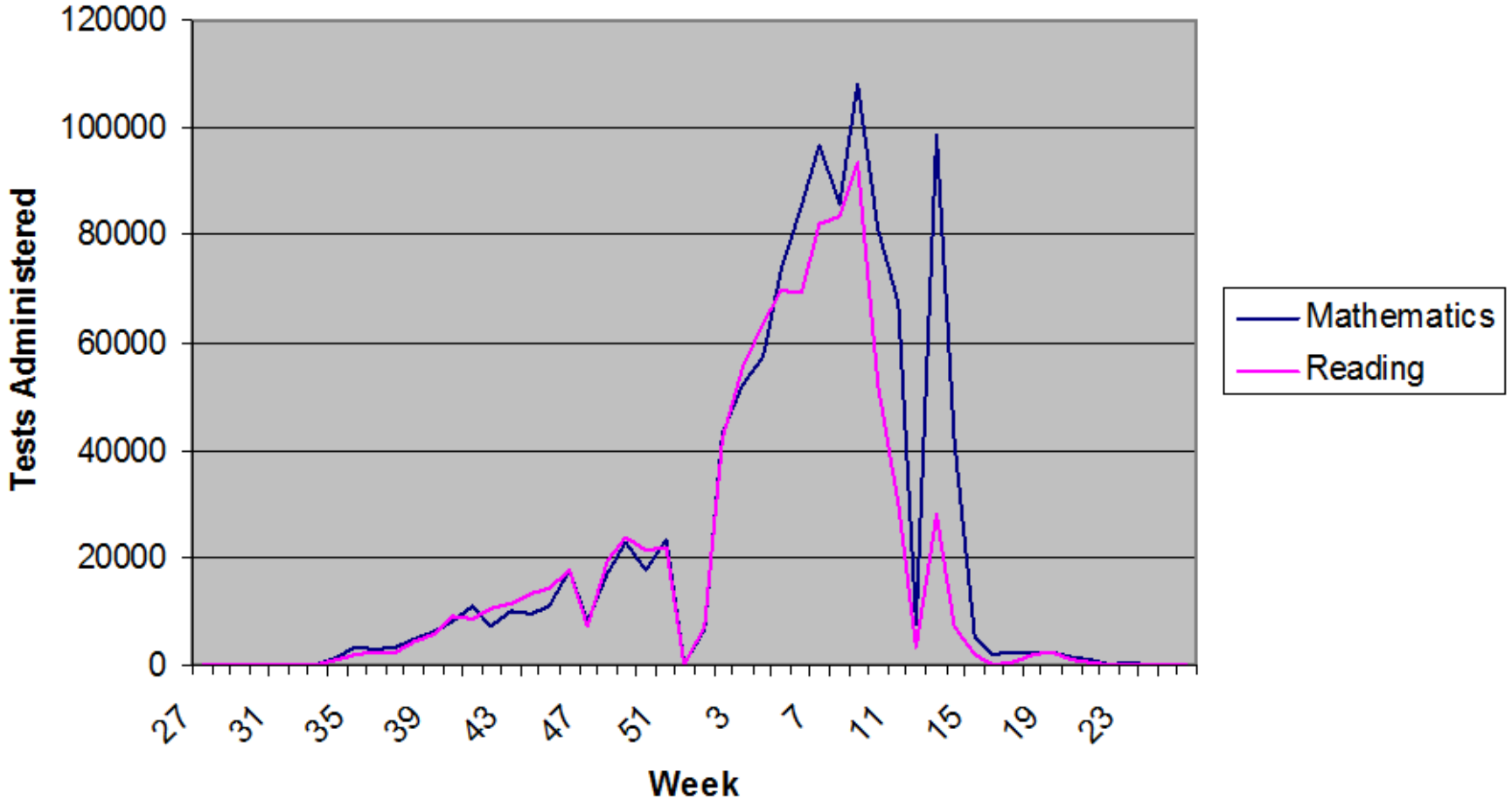
Neal Kingston and Brooke Nash, *Psychology and Research in Education, University of Kansas*

An effect size of about .70 (or .40–.70) is often claimed for the efficacy of formative assessment, but is not supported by the existing research base. More than 300 studies that appeared to address the efficacy of formative assessment in grades K-12 were reviewed. Many of the studies had severely flawed research designs yielding uninterpretable results. Only 13 of the studies provided sufficient information to calculate relevant effect sizes. A total of 42 independent effect sizes were available. The median observed effect size was .25. Using a random effects model, a weighted mean effect size of .20 was calculated. Moderator analyses suggested that formative assessment might be more effective in English language arts (ELA) than in mathematics or science, with estimated effect sizes of .32, .17, and .09, respectively. Two types of implementation of formative assessment, one based on professional development and the other on the use of computer-based formative systems, appeared to be more effective than other approaches, yielding mean effect size of .30 and .28, respectively. Given the wide use and potential efficacy of good formative assessment practices, the paucity of the current research base is problematic. A call for more high-quality studies is issued.

Two challenges in research of efficacy of formative assessment

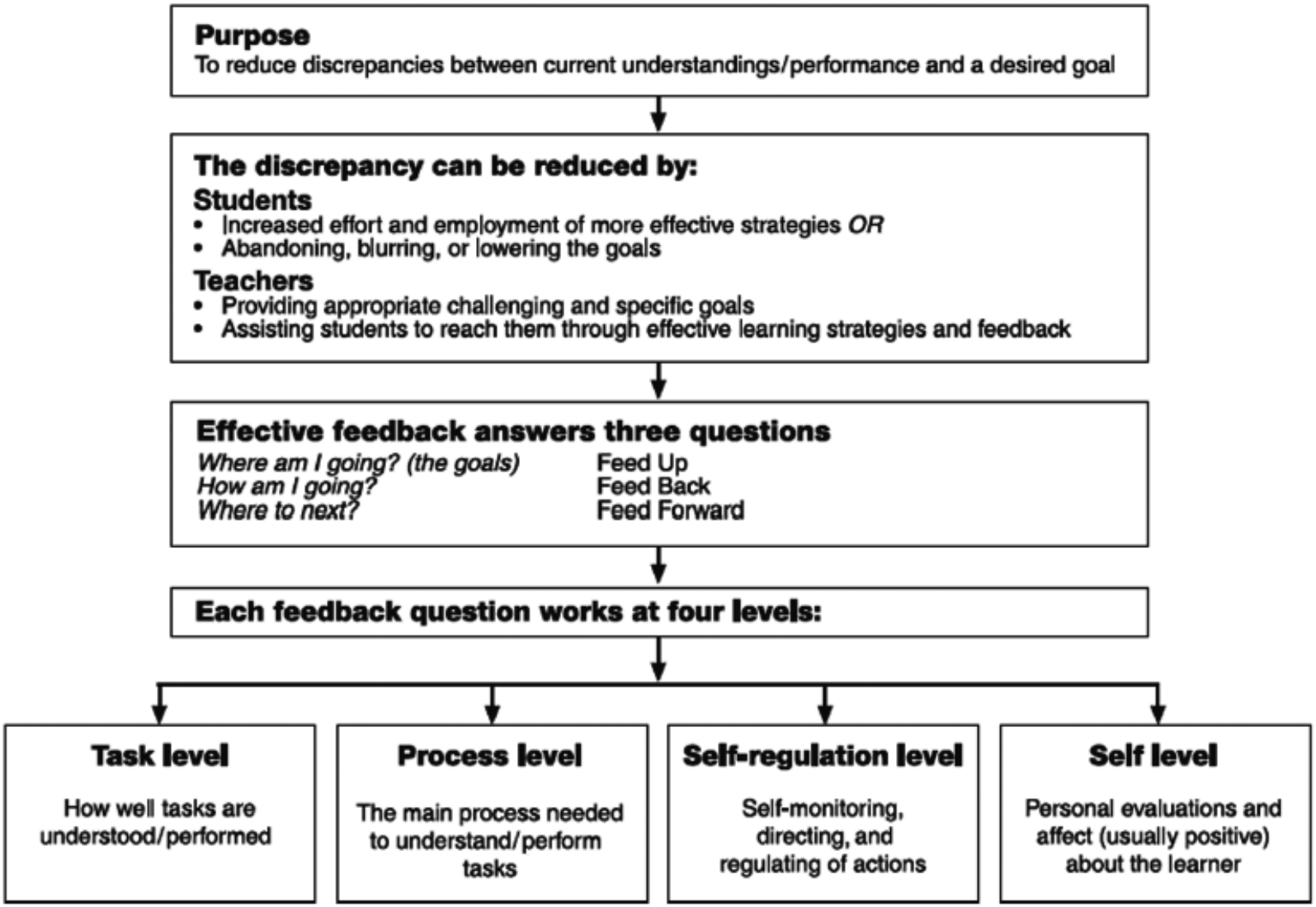
- Anyone can call anything formative assessment
- What is going on in the control group

Usage patterns for the Kansas formative assessment tools in 2007-2008

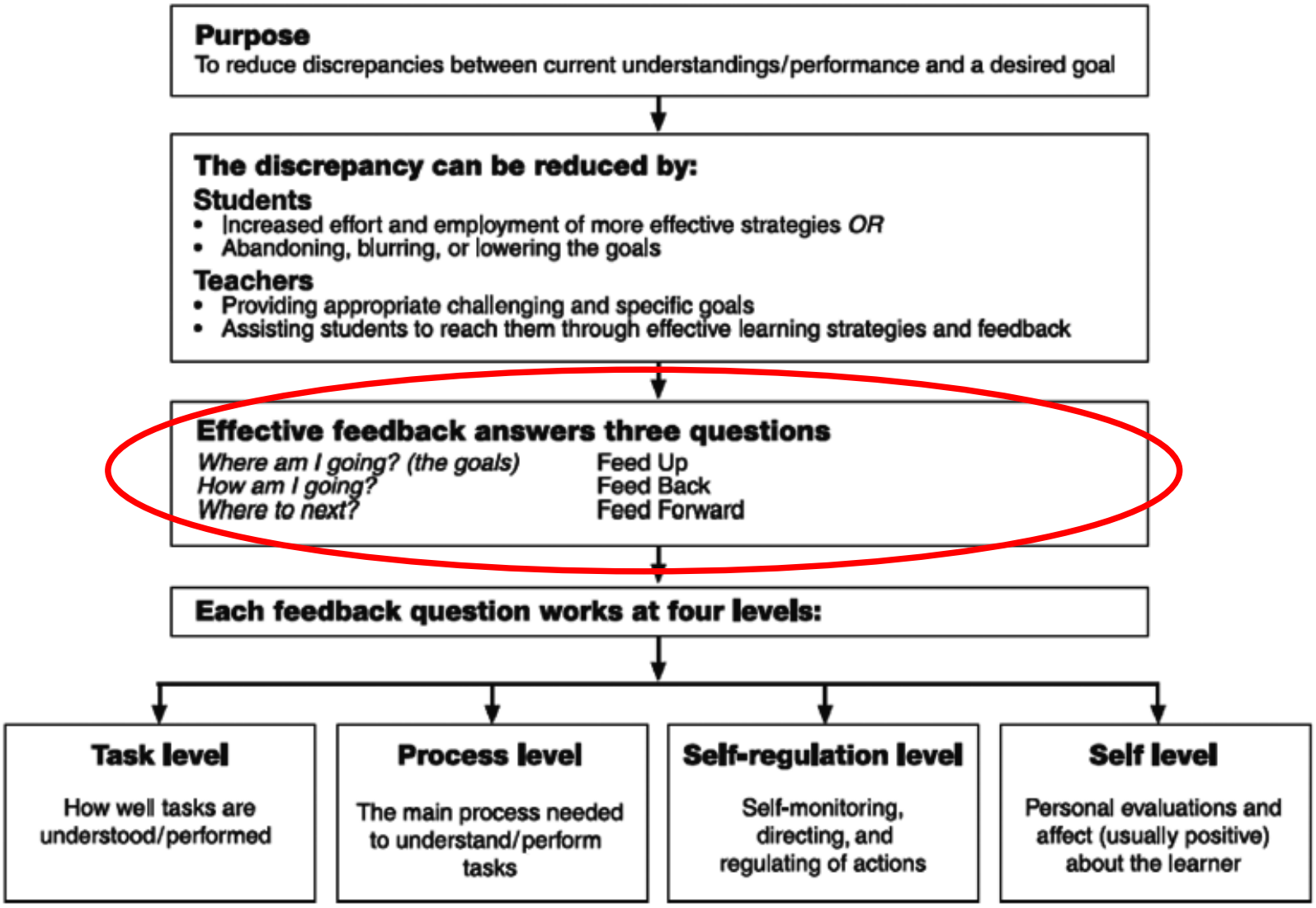


Formative assessment is a form of structured feedback

Hattie and Timperly studied efficacy of feedback in 2007

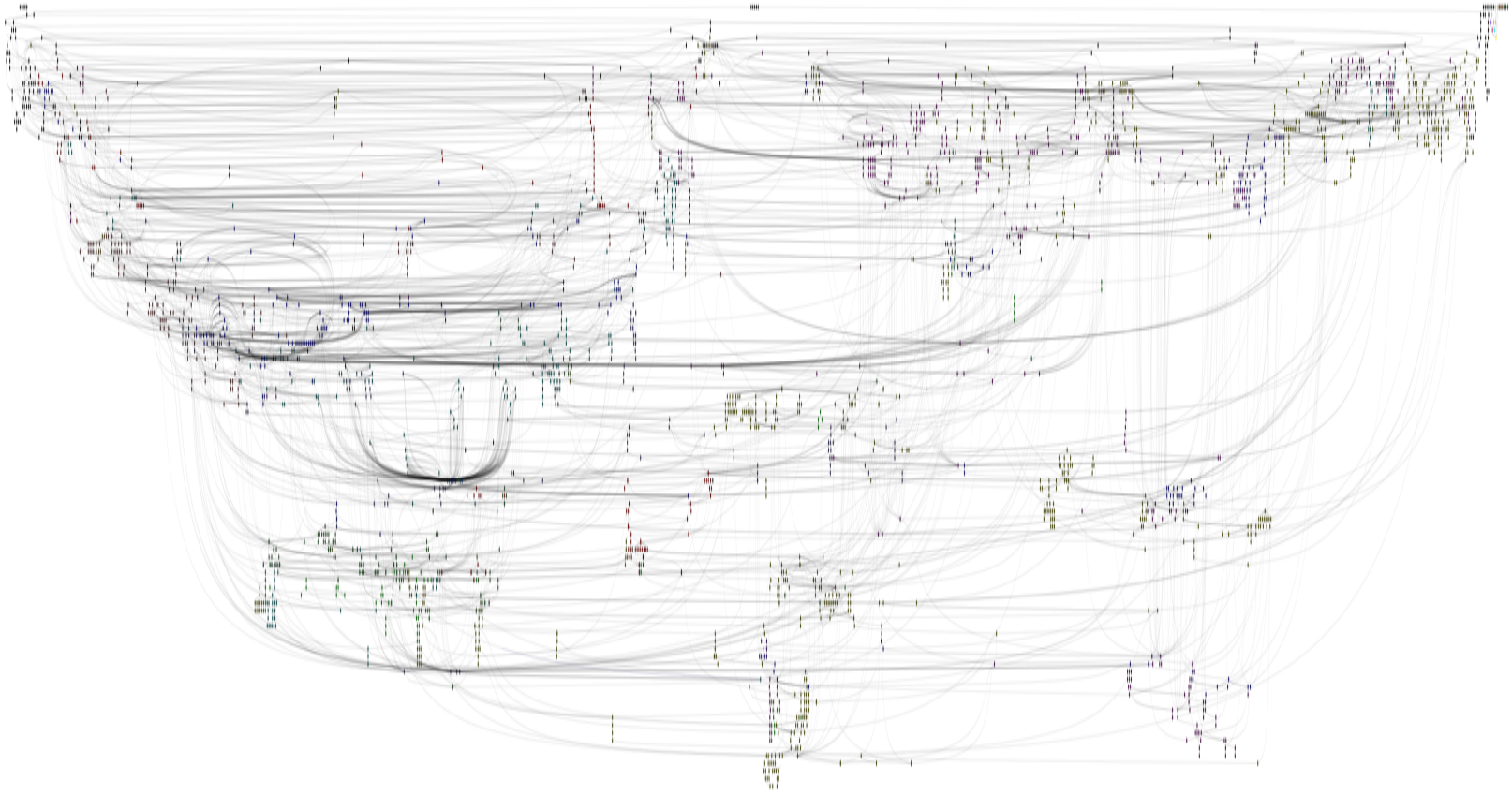


Hattie and Timperly studied efficacy of feedback in 2007

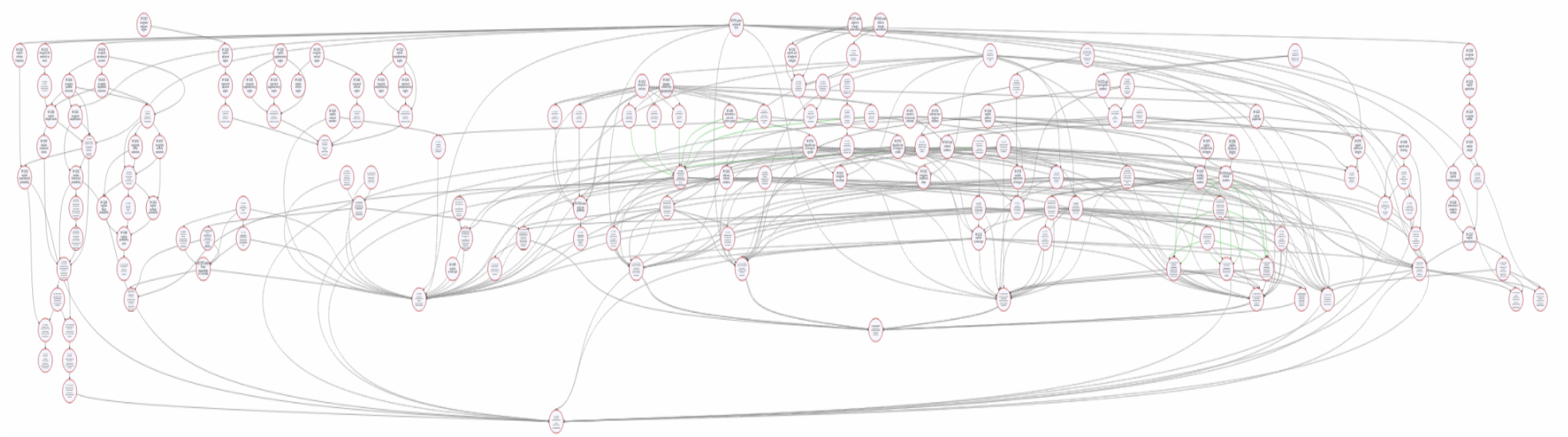


Which brings us to learning maps

The mathematics learning map system, with 2,554 nodes and 5,605 connections.



The grade 7 portion of the mathematics learning map system.



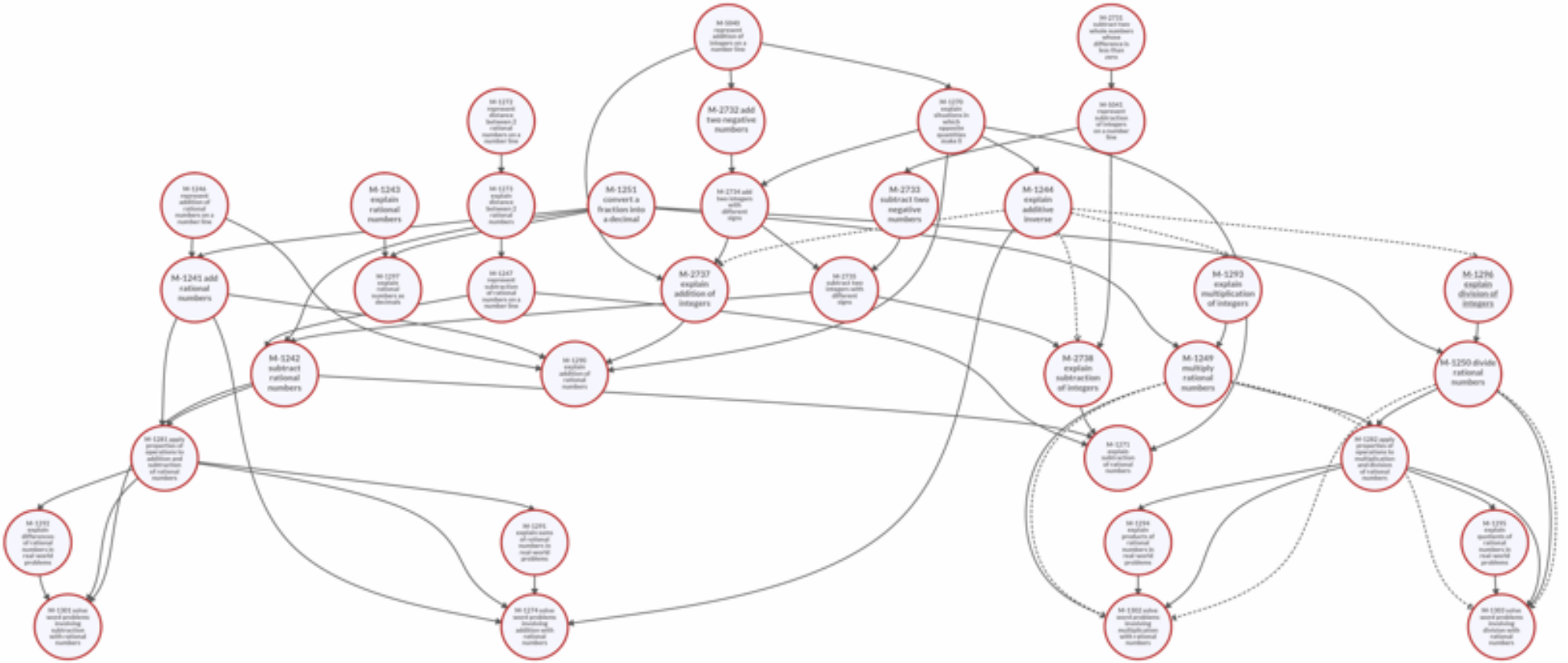
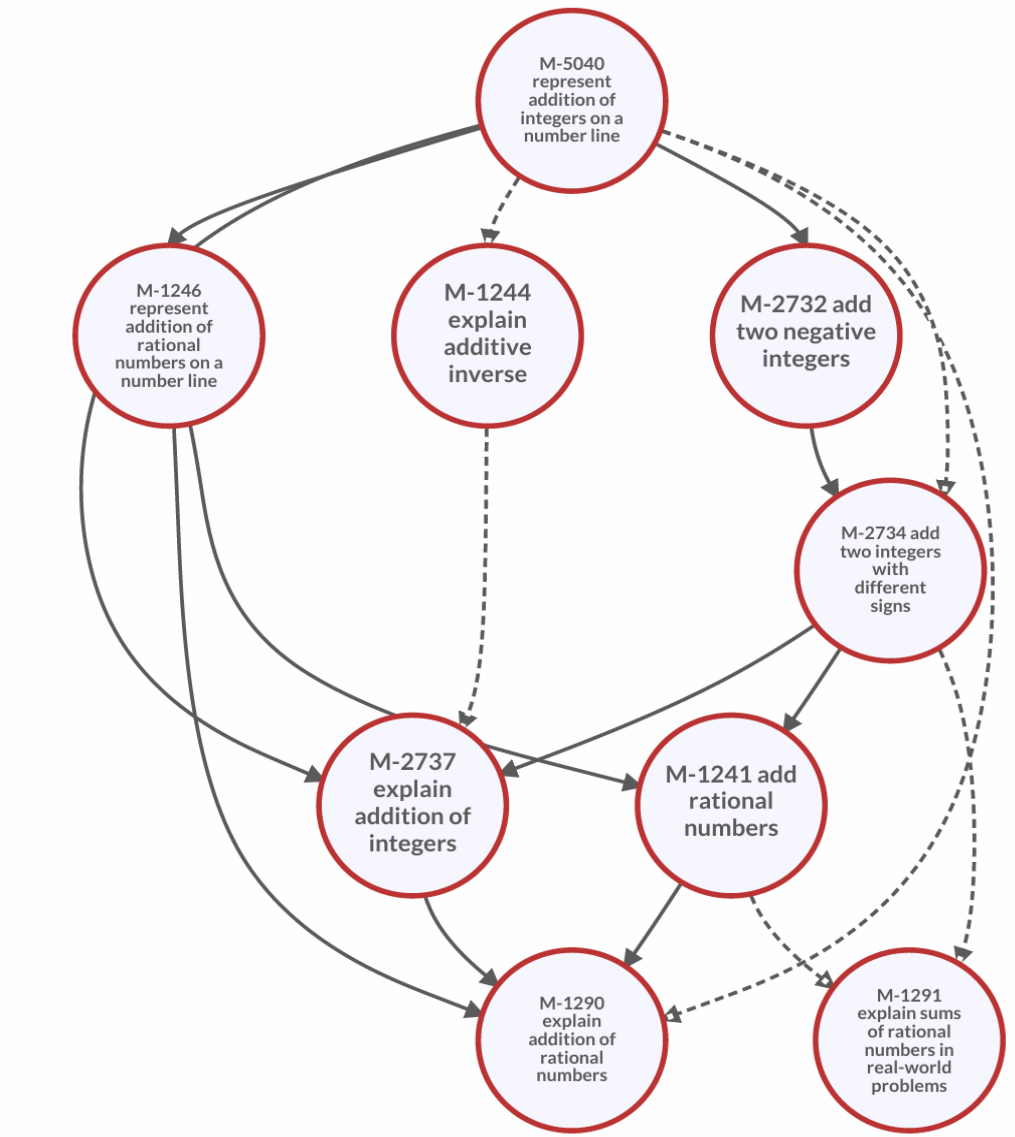
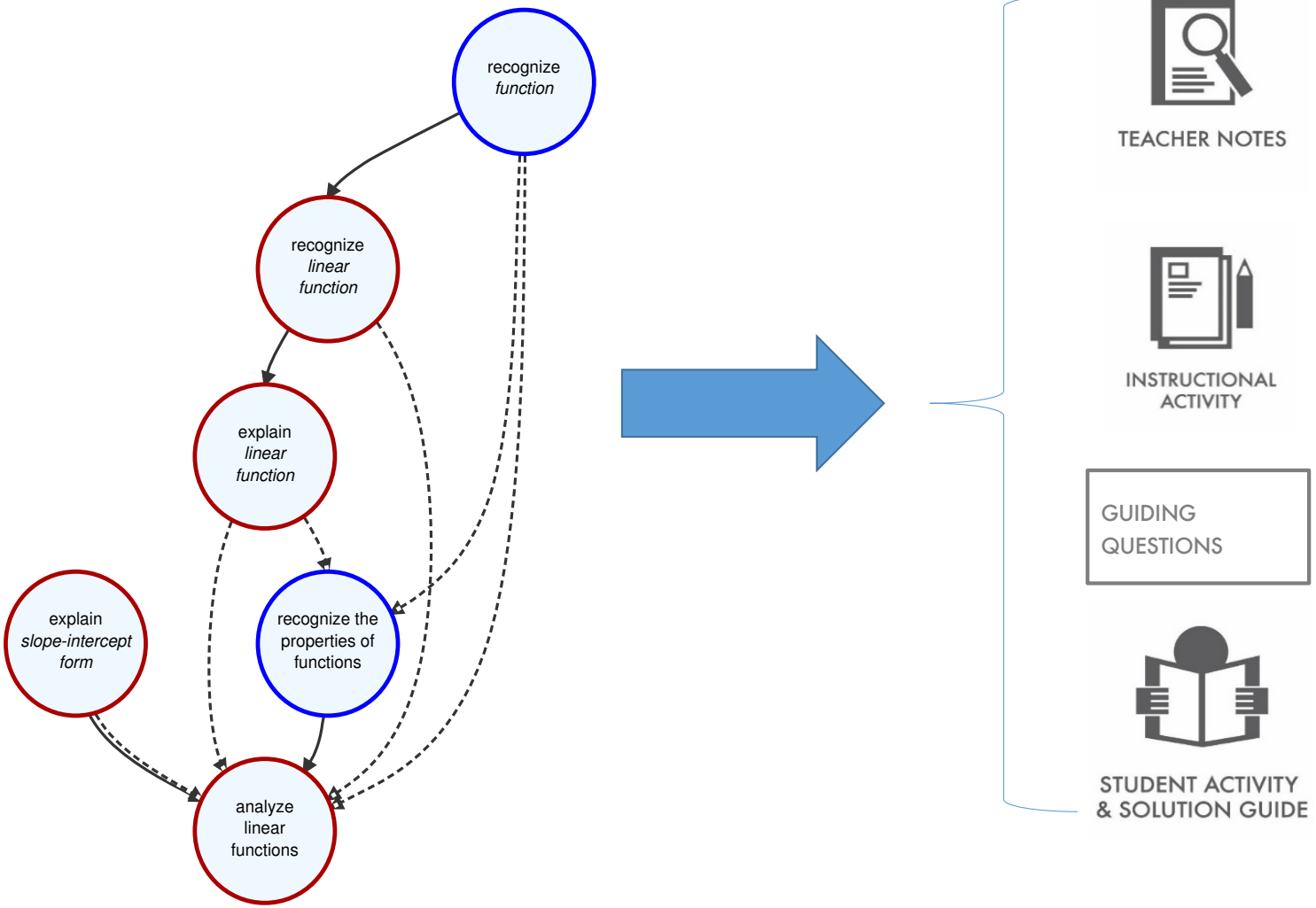


Figure 5. A section of the mathematics learning map system showing the 36 nodes and 57 connections related to grade 7's study of number systems.

The portion of the mathematics learning map system related to the addition of rational numbers.

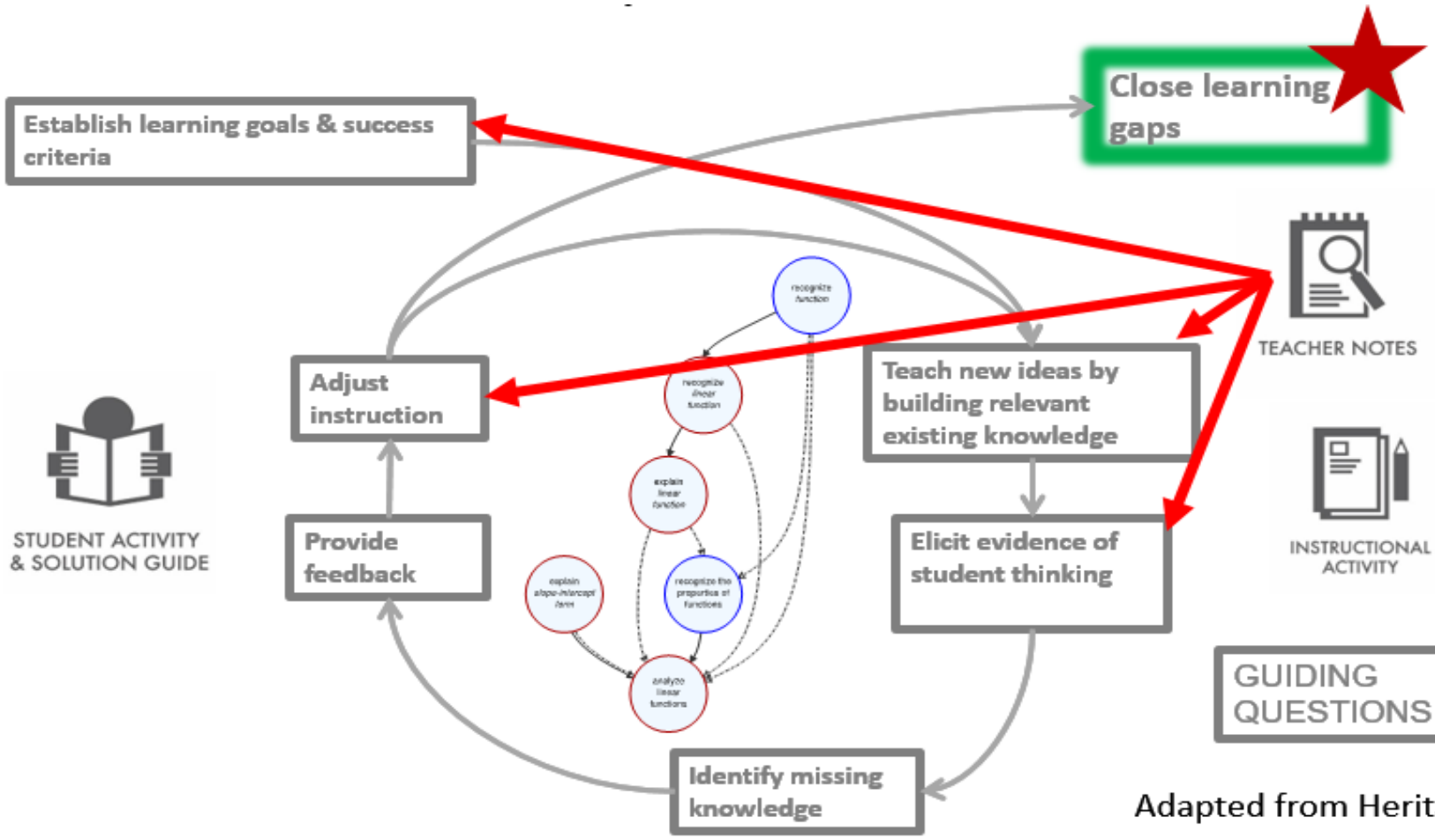


Learning maps can be used as an organizing structure for formative assessment



Instructional materials for an informed instructional system.

Informed instructional system within an adapted version of Heritage's formative assessment approach.



Adapted from Heritage, 2010

Informed instructional system within an adapted version of Heritage's formative assessment approach.

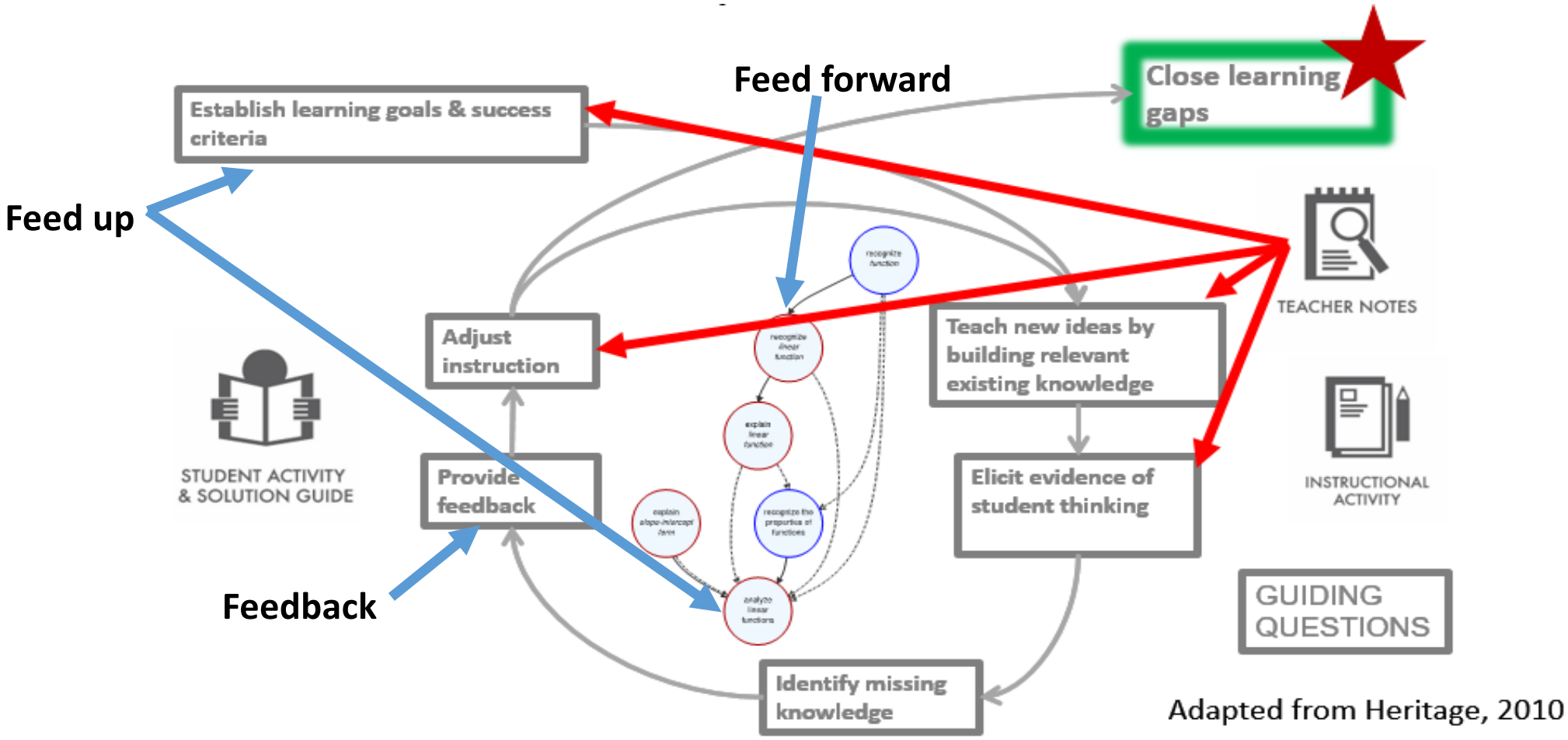


Table 1. The Correspondence of the Instructional Materials to the Informed Instruction System Steps

		Instructional Materials			
		Teacher Notes	**Instructional Activities**	**Guiding Questions**	**Student Activity & Solution Guide**
Informed Instruction System Steps	Establish learning goals & success criteria	X			
	Teach new ideas by building relevant existing knowledge	X	X	X	
	Elicit evidence of student thinking	X	X	X	X
	Identify missing knowledge		X	X	X
	Provide feedback		X		X
	Adjust instruction	X			X

Note. The steps of the informed instruction system are adapted from Heritage's 2010 model [14].

Kindergarten	1st Grade	2nd Grade	3rd Grade	4th Grade	5th Grade	6th Grade	7th Grade	8th Grade	High School
Operations & Algebraic Thinking						Expressions & Equations			Algebra
K.OA	1.OA	2.OA	3.OA	4.OA	5.OA	6.EE	7.EE	8.EE	A-
Counting & Cardinality			Numbers & Operations - Fractions			Ratios & Proportions		Functions	
K.CC			3.NF	4.NF	5.NF	6.RP	7.RP	8.F	F-
Numbers & Operations - Base Ten						The Number System			Number & Quantity
K.NBT	1.NBT	2.NBT	3.NBT	4.NBT	5.NBT	6.NS	7.NS	8.NS	N-
Measurement & Data						Statistics & Probability			
K.MD	1.MD	2.MD	3.MD	4.MD	5.MD	6.SP	7.SP	8.SP	S-
Geometry									
K.G	1.G	2.G	3.G	4.G	5.G	6.G	7.G	8.G	G-

8.SP.1-3

N-Q.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
S-ID.1: Represent data with plots on the real number line (dot plots, histograms, and box plots).
A-REI.10: Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).

...done

ENHANCED LEARNING MAPS

8.SP.1-3

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Map View Info

Map View Info | Resources | Node Table

Standards | My Map Views | Discussion

Student Locater Tool

Map Title: 8.SP.1-3

Map Description:

Save Map

Click below to save a copy of the current map view.

Save Copy of Current Map

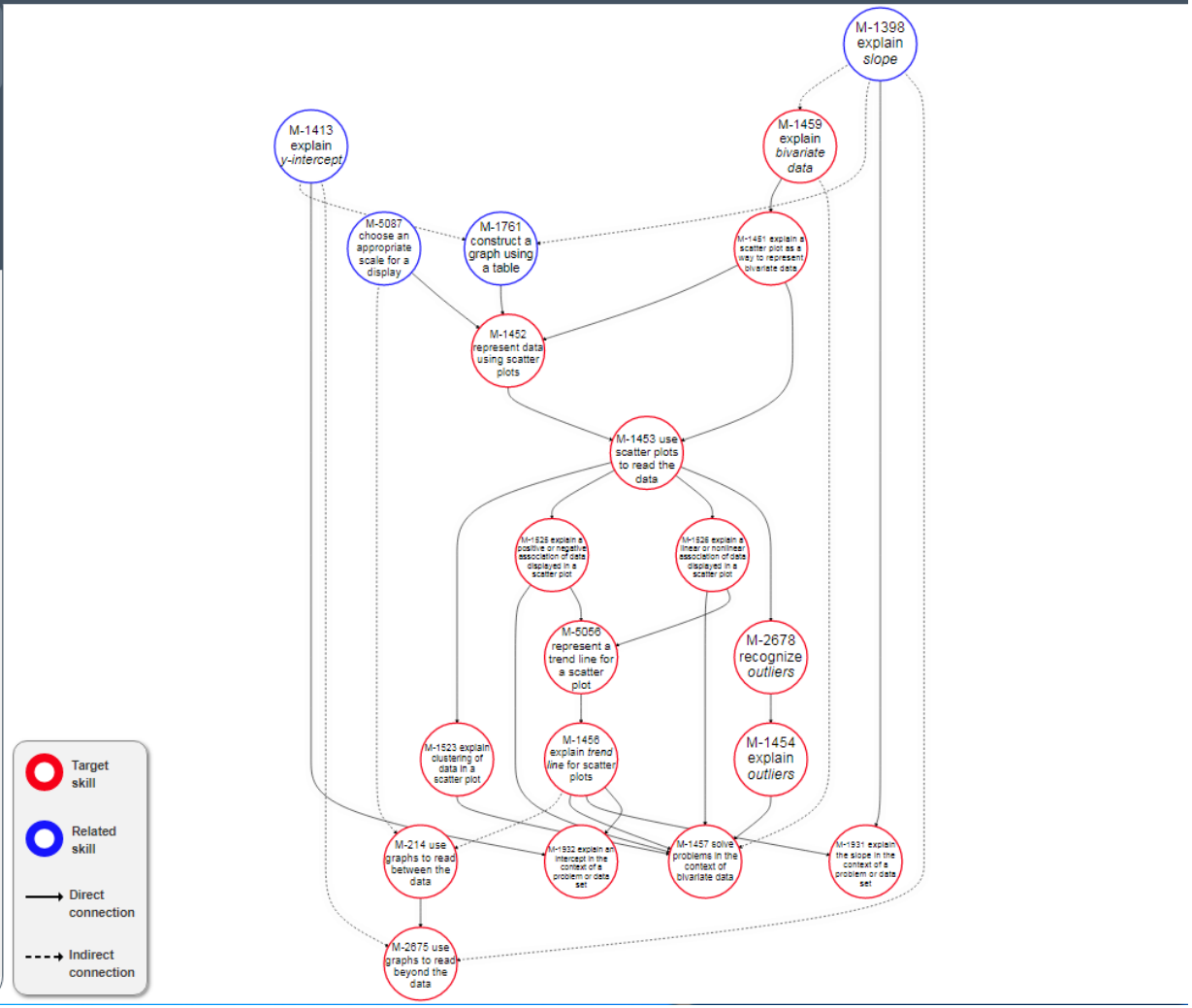
Print Centered Map

Print a copy of the current map centered in the middle of the page.

Print Centered Map

Print Visible Map

Print a copy of the current map as it is seen in the window. **Note:** Only visible



ENHANCED LEARNING MAPS

8.SP.1-3

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Node Table

Map View Info | Resources | Node Table

Standards | My Map Views | Discussion

Student Locater Tool

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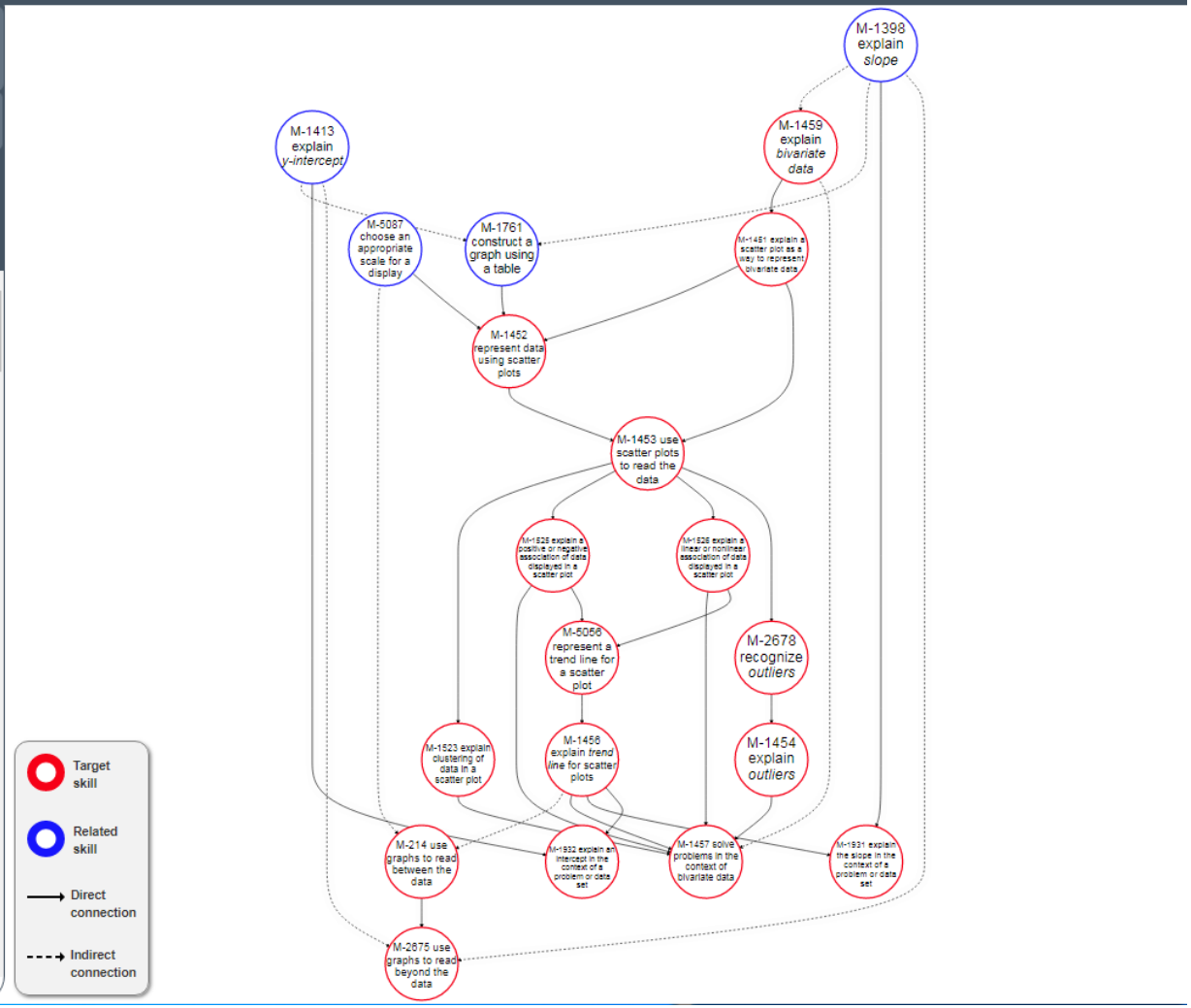
Node ID	Title	Description	Standards
M-214	use graphs to read between the data	Answer questions that require interpretation and integration of information presented in a graph.	2.MD.10 S-ID.1 3.MD.3 6.SP.5.c 4.MD.4 5.MD.2 8.SP.1
M-1398	explain *slope*	Make known your understanding that the slope of a line is the steepness of the line as a ratio. Describe *slope* as rise over run or the	8.EE.5 8.EE.6



ENHANCED LEARNING MAPS

8.SP.1-3

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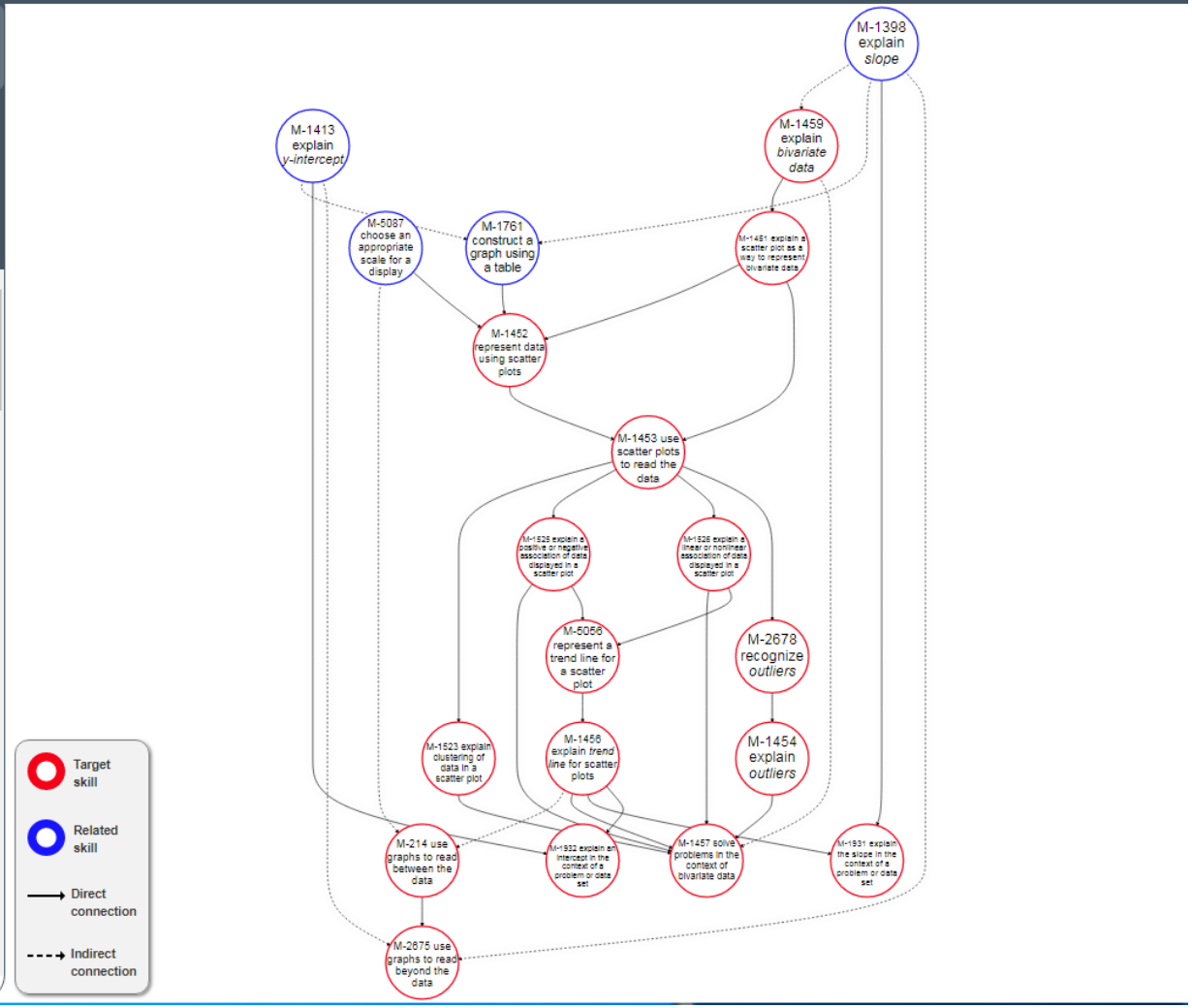
Resources

Map View Info | Resources | Node Table

Standards | My Map Views | Discussion

Student Locater Tool

Scatter Plots and Trend Lines	Students will create bivariate data sets, analyze their data, and determine trend lines. Activities focus on students' interpreting the meaning of individual points, the trend line, and its slope in terms of the context of the data. 8.SP.1-3 Student Word Documents	8.SP.1-3
Scatter Plots and Trend Lines (Alaska)	Students will create bivariate data sets, analyze their data, and determine trend lines. Activities focus on students' interpreting the meaning of individual points, the trend line, and its slope in terms of the	8.SP.1-3



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Achievement & Assessment Institute

SCATTER PLOTS AND TREND LINES

8.SP.1, 8.SP.2, and 8.SP.3

Contributing Author: Natasha Cox

CONTENTS

The types of documents contained in the unit are listed below. Throughout the unit, the documents are arranged by lesson.

SCATTERPLOTS AND TREND LINES

OVERVIEW OF INSTRUCTIONAL ACTIVITIES

Lesson	Learning Goal	Nodes Addressed
Lesson 1	Students will create a scatterplot with appropriately labeled and scaled axes and estimate new data values. The critical outcome of this activity is for students to recognize scatter plots as tools for graphing bivariate data and to construct scatter plots accurately.	▶ EXPLAIN *BIVARIATE DATA* ▶ CHOOSE THE APPROPRIATE GRAPH FOR A GIVEN SET OF DATA ▶ CHOOSE AN APPROPRIATE SCALE FOR A DISPLAY ▶ USE SCATTERPLOTS TO READ THE DATA ▶ EXPLAIN A SCATTERPLOT AS A WAY TO REPRESENT BIVARIATE DATA ▶ USE GRAPHS TO READ BEYOND THE DATA
Lesson 2	Students will use a scatter plot to identify outliers and clusters, estimate a linear model, and use the linear model to make predictions. The critical outcome of this activity is for students to identify outliers on a scatter plot, informally draw and assess the accuracy of a trend line, and use the trend line to make predictions. Additionally, students should be able to identify the *y*-intercept and slope of a trend line and to describe what they mean in terms of the data.	▶ EXPLAIN *OUTLIERS* ▶ EXPLAIN CLUSTERING OF DATA IN A SCATTERPLOT ▶ USE GRAPHS TO READ BETWEEN THE DATA ▶ USE GRAPHS TO READ BEYOND THE DATA ▶ EXPLAIN A LINEAR OR NONLINEAR ASSOCIATION OF DATA DISPLAYED IN A SCATTERPLOT ▶ REPRESENT A TREND LINE FOR A SCATTERPLOT ▶ EXPLAIN AN INTERCEPT IN THE CONTEXT OF A PROBLEM OR DATA SET ▶ EXPLAIN THE SLOPE IN THE CONTEXT OF A PROBLEM OR DATA SET
Lesson 3	Students determine the trend line equation that is most appropriate for a scatter plot. The critical outcome of this activity is for students to describe and identify an appropriate trend line for any data set and represent positive and negative linear association, nonlinear association, and no association in scatter plots.	▶ EXPLAIN *TREND LINE* FOR SCATTERPLOTS ▶ EXPLAIN AN INTERCEPT IN THE CONTEXT OF A PROBLEM OR DATA SET ▶ EXPLAIN THE SLOPE IN THE CONTEXT OF A PROBLEM OR DATA SET ▶ EXPLAIN A LINEAR OR NONLINEAR ASSOCIATION OF DATA DISPLAYED IN A SCATTERPLOT

Scatter Plots and Trend Lines

INSTRUCTIONAL ACTIVITY

Lesson 1

LEARNING GOAL

Students will create a scatterplot with appropriately labeled and scaled axes and estimate new data values. The critical outcome of this activity is for students to recognize scatter plots as tools for graphing bivariate data and to construct scatter plots accurately.

PRIMARY ACTIVITY

Students will measure the lengths of their feet and their heights and record the results. The students will then graph the results on a scatter plot.

OTHER VOCABULARY

Students will need to know the meaning of

- Independent variable
- Dependent variable
- Scatter plot
- Bivariate data
- Linear function graph

MATERIALS

- Rulers with centimeter markings (for measuring foot length)
- Tape measures or yard sticks with centimeter markings (for measuring height)
- Graph paper

IMPLEMENTATION

This lesson begins with students collecting data to create a scatter plot to answer the question, "Is there a relationship between a person's foot length and a person's height?"

Students should measure the lengths of their feet and their heights and record the results as a T-chart. Foot length should be measured to the nearest tenth of a centimeter, whereas height can be measured to the nearest centimeter. These results will need to be available to all students.

Review a few of the other graphical displays students have learned before introducing the concept of a scatter plot (these will most likely be displays that are only appropriate for one-variable data). Showing the students examples of each type of display may help explain why the displays are inappropriate to represent pairs of numbers. In addition, some displays (pie charts, bar graphs, and line graphs) are only appropriate for categorical data, while the class's data are quantitative.

GUIDING QUESTIONS

Elicit student thinking:

- How can we represent these data in other ways?
- What are some graphs you have used before?
- Have you worked with tables like this (i.e., T-charts) before? For what purpose?

Determine if the student can EXPLAIN *BIVARIATE DATA*:

- How would our data be different if we had only measured our heights?
- What patterns or relationships exist in our data?

Determine if the student can CHOOSE THE APPROPRIATE GRAPH FOR A GIVEN SET OF DATA (use the graph types the student mentioned previously):

- Can you represent the data as a pie chart, bar graph/histogram, box plot? Why or why not?
- How have you graphed information from two-column tables before?
- What pattern did you usually see when you graphed information from two-column tables? (The points lined up.)

GUIDING QUESTIONS

Elicit student thinking:

- What should you consider as you set up a graph?

Determine if the student can CHOOSE AN APPROPRIATE SCALE FOR A DISPLAY:

- Do all axes on graphs need to start at zero?
- Do the *x*- and *y*-axes need to have the same scale?
- Do all points need to fit on the scatter plot?
- Do the tic marks on an axis need to be evenly spaced?
- Do the tic marks on an axis need to represent equal intervals?
- Does a person's height depend on foot length? Does a person's foot length depend on height?
- Does it matter whether the *x*-axis represents foot length or height?
- [Direct students to draw a scale for the *x*-axis and for the *y*-axis.] Is there anything missing? Will someone who doesn't know what the numbers mean be able to understand your scatter plot?

ERRORS, MISCONCEPTIONS, AND MISSING KNOWLEDGE

Example Error	Misconception	Missing Knowledge
The student identifies a negative association instead of positive association in the scatter plot.	may be reading the data from right to left instead of left to right or confusing positive and negative association	EXPLAIN A POSITIVE OR NEGATIVE ASSOCIATION OF DATA DISPLAYED IN A SCATTER PLOT
The student draws a horizontal line or a line through the data points.	knows the trend line needs to go through the center of the data but does not understand what it means to follow the trend of the data	REPRESENT A TREND LINE FOR A SCATTER PLOT
The student draws a line with a positive slope but draws through the point (0, 0) and therefore does not follow the trend of the data or keep the trend line centrally located in the data.	thinks the trend line needs to go through the origin and the center of the data but does not understand what it means to follow the trend of the data	REPRESENT A TREND LINE FOR A SCATTER PLOT
The student does not draw a straight line and/or tries to connect each point in the scatter plot.	does not understand that a trend line must be a single, straight line and that it does not need to go through every point on the scatter plot	REPRESENT A TREND LINE FOR A SCATTER PLOT

Teachers liked it and felt it to be useful

Comments about Learning Map Information

I was able to work back to my students' level and have a plan of how to reach the grade level standard they are struggling in. I work well with visual aids and this provided exactly that. –Rebecca Warkins

The learning maps have been very helpful in targeting gaps in student learning. The resources have been helpful in closing those gaps. –Suzanne Woodard

Because I have such a diverse learning population, it was nice to have the map to show students a beginning and then show a map of the skills each student would gain in order to show progress. It helps the students stay focused on goals and feel successes. -Donna True

It is helpful to see what skills were necessary to master the targeted standard and where to go next. Several times I thought I knew what skill the student was missing, but when presented with a menu of pathways to take, my students gained more ground. –Deb Martin

Comments about Teacher Notes

I think the teacher notes are much easier to read than the standards so I like them. -Donna True

I found the student misconceptions very helpful. Also, appreciated how the research findings are paired with learning activities, approaches, and strategies. –Suzanne Woodard

These notes are quite extensive. I do not feel as confident teaching math, and with the Common Core standards, was unfamiliar with some of the models/strategies used in multiplying beyond the standard algorithm. The notes explained and modeled the strategy so that I could feel confident in teaching them. I also learned what common misconceptions were and how to address them. This helped immensely when organizing my small group intervention. Also, when planning lessons it gave me a rationale for the order in which I was teaching, beyond just that's how the textbook ordered it. The step by step directions of what to ask, model, require, explain, etc. helped my keep the lesson focused. –Deb Martin

I felt that my students were beginning to get the why behind what they were doing. – Deb Martin

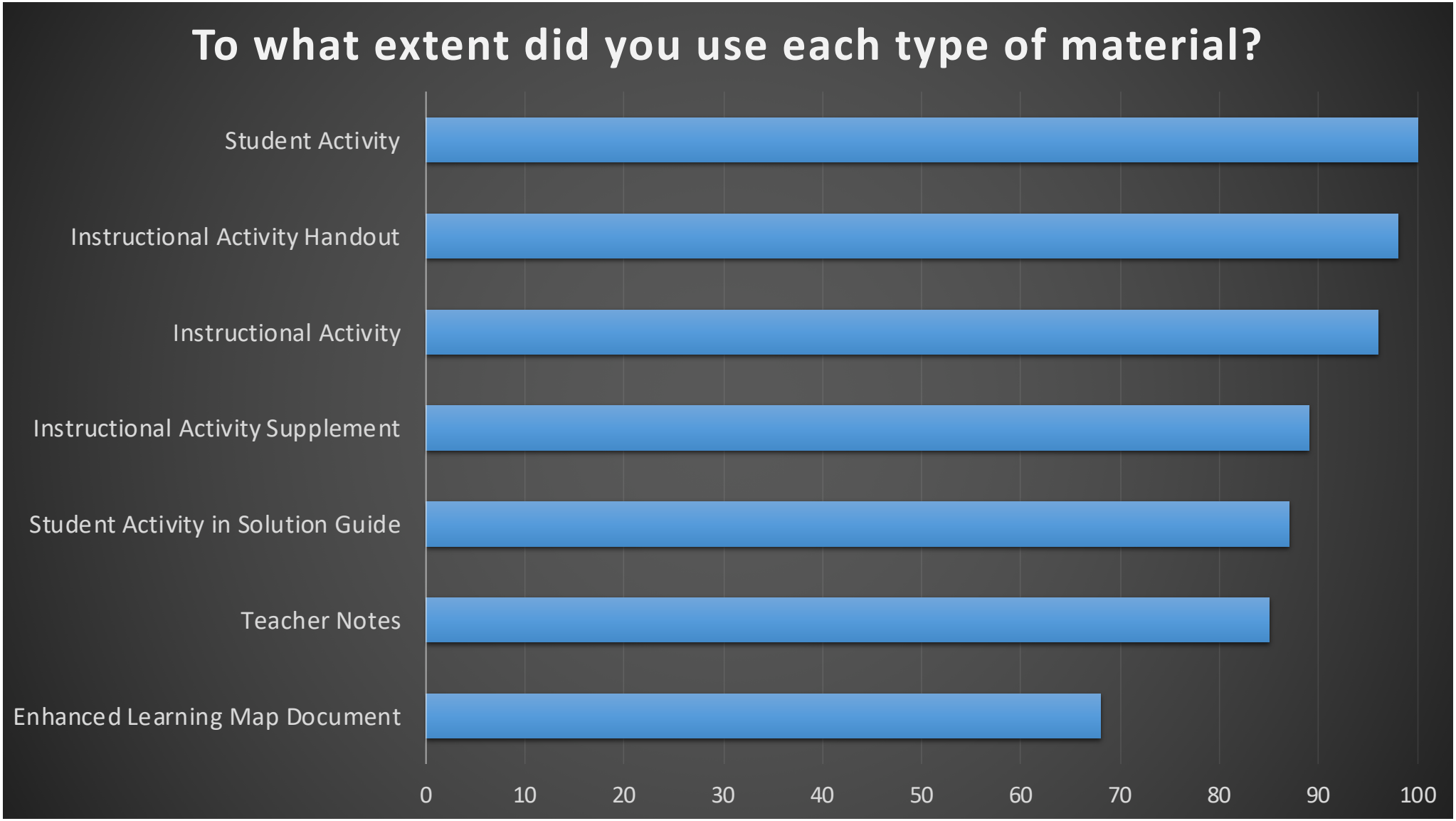
Comments about Instructional Activities

I felt the guiding questions were very thorough and gave me a lot of insight as to what the students were thinking and misconceptions they had. –Rebecca Warkins

I love the support given to teachers, especially if these models are new to you, as they were to me. I still feel like I need to study these in depth before teaching, and that's ok. With the amount of explanation given I feel better equipped to teach. –Deb Martin

I think it is all very useful. I like the way the resources are laid out, easy to read, and EASY to implement. Not too much prep involved. Very doable. –Suzanne Woodard

I really like the notes and the activity instructions. Again, I don't particularly feel like I know all of the strategies and standards to the point that I could explain the why to what I am doing. The notes and activities are so thorough in that I have been able to explain to my teaching team what the standard is actually saying and how to effectively teach it. – Deb Martin


To what extent did you use each type of material?
Student Activity
Instructional Activity Handout
Instructional Activity
Instructional Activity Supplement
Student Activity in Solution Guide
Teacher Notes
Enhanced Learning Map Document
0
10
20
30
40
50
60
70
80
90
100

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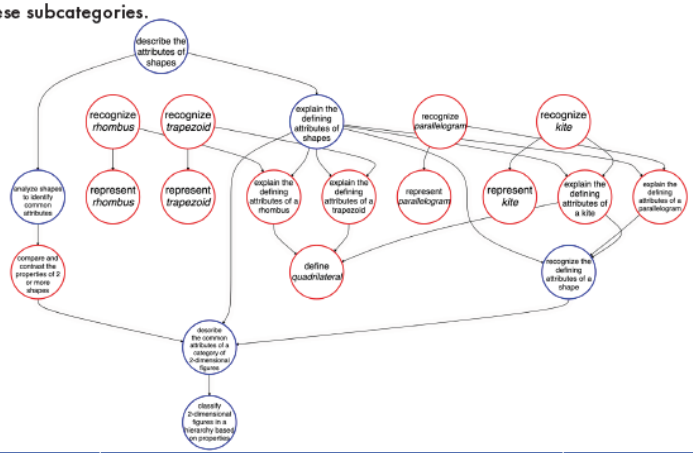
STANDARD **AT A GLANCE**

3.G.1 Understand that shapes in different categories (e.g., rhombuses, rectangles, and others) may share attributes (e.g., having four sides), and that the shared attributes can define a larger category (e.g., quadrilaterals). Recognize rhombuses, rectangles, and squares as examples of quadrilaterals, and draw examples of quadrilaterals that do not belong to any of these subcategories.



Precursor Skills: Skills that precede the target skills	Target Skills: Skills closely aligned with the standard			Successor Skills: Skills that are a step beyond the target skills
describe the attributes of shapes	recognize *rhombus*	represent *rhombus*	explain the defining attributes of a rhombus	recognize the defining attributes of a shape
analyze shapes to identify common attributes	recognize *trapezoid*	represent *trapezoid*	explain the defining attributes of a trapezoid	describe the common attributes of a category of 2-dimensional figures
explain the defining attributes of shapes	recognize *parallelogram*	represent *parallelogram*	explain the defining attributes of a parallelogram	classify 2-dimensional figures in a hierarchy based on properties
	recognize *kite*	represent kite	explain the defining attributes of a kite	
	define *quadrilateral*	compare and contrast the properties of 2 or more shapes		

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INSTRUCTIONAL STRATEGIES

Students need to develop spatial sense through consistent, meaningful activities with shapes to be able to recognize and draw shapes with specific attributes. (Van de Walle, Lovin, Karp, Bay-Williams, 2014).

Activities need to give students experience with examples and non-examples of given shapes, including shapes in a variety of sizes and orientations, materials, and colors to help students generalize this knowledge (Clements & Sarma, 2000; Hourigan & Leavy, 2015; Van de Walle, et al., 2014).

Activities should give students opportunities to describe different shapes and the shapes' attributes both orally and through writing (Van de Walle, et al., 2014).

Questions to guide discussions may include:

- What shapes do you see?
- [*Point to a shape the student recorded.*] What shape is this?
- [*Point to a shape the student recorded.*] How do you know this is a [name of shape]?
- Describe everything you notice about this shape.
- [*Show the same shape in two different sizes/colors/orientations.*] Are these the same shape? How do you know?
- [*Point to a shape.*] What do you notice about all of these shapes?
- [*Turn the student's paper so a shape has a different orientation.*] Is this the same shape as before? How do you know?
- [*Show a specific quadrilateral.*] Find all examples of this shape. What are the properties that belong to this shape? Point to the parts of the shape that show each property.
- [*Show two different shapes.*] Do these two shapes share any properties? What properties do they not share?

REFERENCES

Clements, D., & Sarma, J. (2000). Young children's ideas about geometric shapes. Teaching children mathematics 6(8), 482-488.

Hourigan, M., & Leavy, A. (2015). What's a real 2D shape?: Designing appropriate geometric instruction. Australian primary mathematics classroom, 20(1), 24-29.

Van de Walle, J., Lovin, L., Karp, K., Bay-Williams, J. (2014). Teaching student-centered mathematics: Develop.

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Efficacy

- Preliminary results based on only one of the three states that provided data
  - Hot off the press (analyses performed October 23rd)
- Data from other states will be added in as soon as available

Students in participating classrooms were matched with students in non-participating classrooms

- 2018 and 2019 test scores were standardized
  - 2018 scores are from grade X-1 and were one of three variables used for matching, the others being gender and school district type
- Used R Matchit package to do nearest neighbor propensity score match, sampling from about 35,000 non-participating students
  - Did not stratify within classroom which might have an impact, though it would likely be very small


I HAVE ATTEMPTED SCIENCE
PLEASE EXPLAIN
I FORMED AN IDEA AND THEN DISCOVERED I WAS WRONG.
THERE ARE NUMEROUS DIAGRAMS
I WAS WRONG IN NUMEROUS WAYS
I PRODUCED A DETAILED TRIBUTE TO MY WRONGNESS
THAT IS SCIENCE
NATHANWPYLE

Quality of ELA Match (2018 Data for Grade - 1)

Grade	Group	Mean	SD	n
5	Non-ELM	-.09	.92	48
	ELM	-.09	.92	48
6	Non-ELM	-.25	.58	11
	ELM	-.25	.58	11
7	Non-ELM	.11	.92	16
	ELM	.11	.92	16

Quality of Math Match (2018 Data for Grade - 1) Before Dropping School Type

Grade	Group	Mean	SD	n
4	Non-ELM	.06	1.06	41
	ELM	.07	1.04	41
5	Non-ELM	-.16	.84	104
	ELM	-.16	.84	104
6	Non-ELM	.19	.89	198
	ELM	.19	.89	198
7	Non-ELM	-.16	.71	150
	ELM	-.16	.71	150
8	Non-ELM	.26	.69	13
	ELM	.26	.69	13

There were insufficient students from charter schools in the Grade 4 non-ELM group to get a good match

Quality of Math Match (2018 Data for Grade - 1) After Dropping School Type

Grade	Group	Mean	SD	n
4	Non-ELM	.07	1.04	41
	ELM	.07	1.04	41
5	Non-ELM	-.16	.84	104
	ELM	-.16	.84	104
6	Non-ELM	.19	.89	198
	ELM	.19	.89	198
7	Non-ELM	-.16	.71	150
	ELM	-.16	.71	150
8	Non-ELM	.26	.69	13
	ELM	.26	.69	13

ELA Results (2019 Data)

Grade	Group	Mean	SD	n	t	p
5	Non-ELM	.10	1.01	48	-1.03	.36
	ELM	-.10	.84	48		
6	Non-ELM	-.20	.52	11	.25	.31
	ELM	-.12	.80	11		
7	Non-ELM	.29	1.06	16	-1.28	.11
	ELM	-.12	.75	16		

Math Results(2019 Data)

Grade	Group	Mean	SD	n	t	p
4*	Non-ELM	-.10	.91	41	1.51	.13
	ELM	.24	1.12	41		
5	Non-ELM	-.16	.85	104	-1.39	.17
	ELM	-.32	.73	104		
6	Non-ELM	.15	.92	198	.49	.63
	ELM	.20	.81	198		
7	Non-ELM	-.19	.82	150	1.07	.28
	ELM	-.08	.91	150		
8	Non-ELM	.19	.79	13	.60	.55
	ELM	.37	.77	13		

Next steps

- Check propensity score matching
  - Check similarity on variables not used in matching
  - Check if there is a better set of matching variables
- Add in data from two other states
- Analyze data by classroom and calculate variance associated with teacher (HLM)