

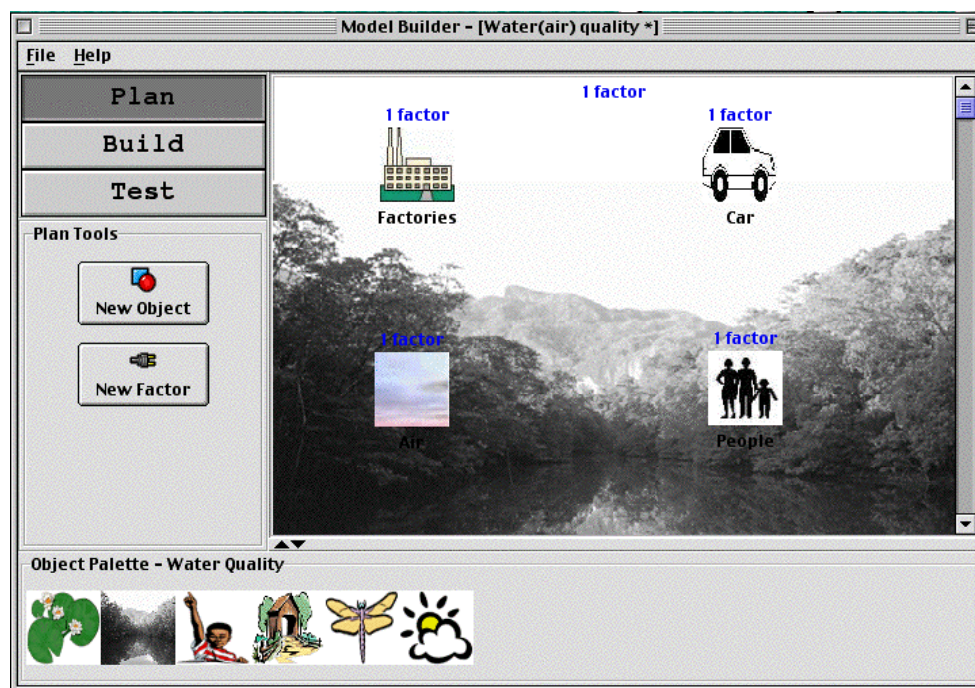


Fig. 1 The graphic interface of Plan mode

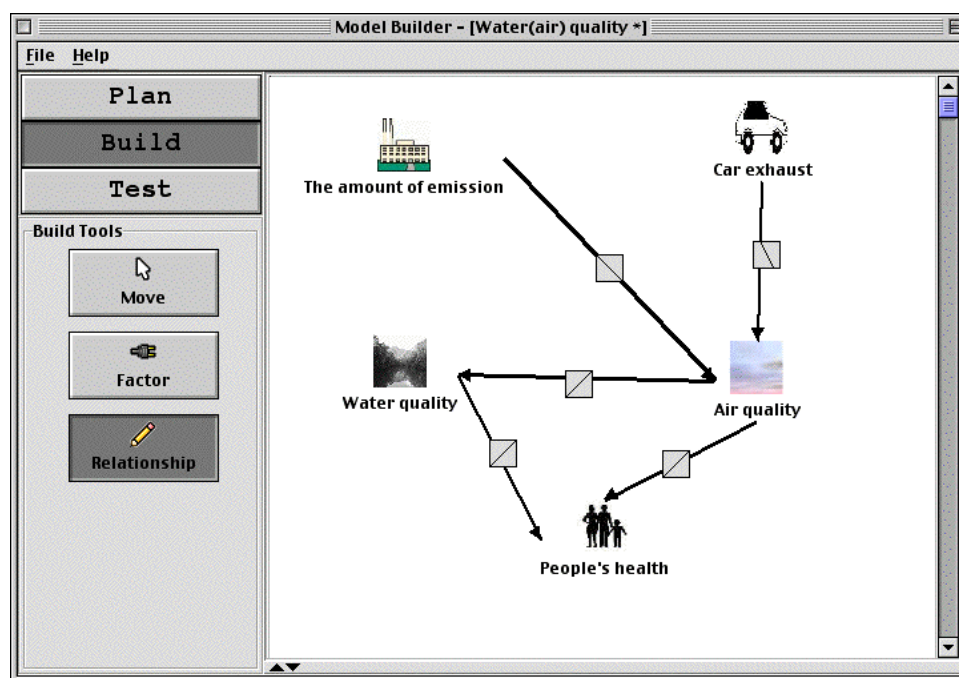


Fig. 2 The graphic interface of Build mode

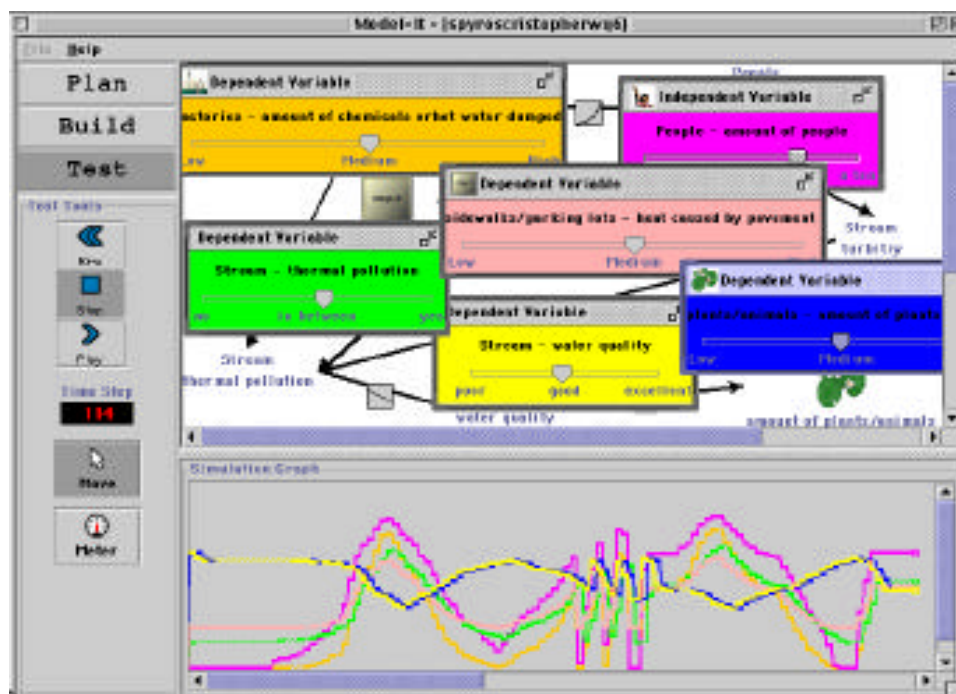


Fig. 3 The graphic interface of Test mode

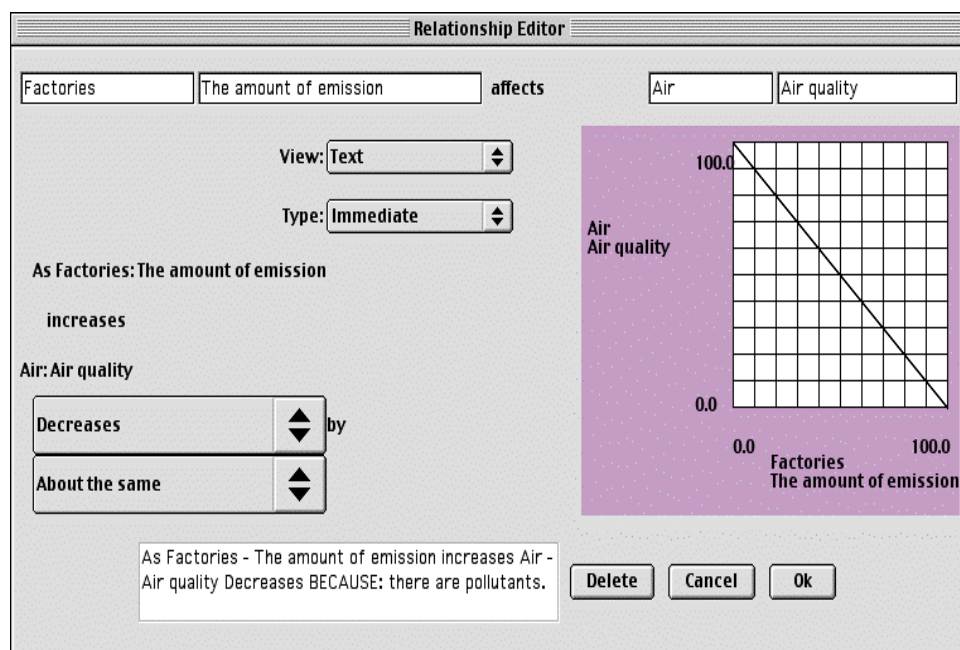


Fig. 4 The relation editor in the Build mode

Table 1

The actions students performed in the plan, build, and test modes.

Mode	Plan	Build	Test
Code number and action	2.1.1 Create object	2.2.1 Create factor	2.3.1 Open meter
	2.1.2 Modify object	2.2.2 Modify factor	2.3.2 Assign factors to graph
	2.1.3 Delete object	2.2.3 Delete factor	2.3.3 Change meter value
	2.1.4 Create factor	2.2.4 Create relationship	2.3.4 Delete meter
	2.1.5 Modify factor	2.2.5 Modify relationship	
	2.1.6 Delete factor	2.2.6 Delete relationship	

Table 2

Modeling strategies and definitions

Code number and strategy	Definition
Planning	
4.1.1 Generating ideas	Students talk about what they are going to model.
4.1.2 Stating goals	Students decide their driving question that could be answered by their model or articulate the types of model they want to have.
4.1.3 Identifying factors or objects	Students mention objects and/or factors that they want to include in their model without further discussion or articulation.
4.1.4 Specifying relationships	Students verbally indicate certain relationships between factors that they want to create for their model.
4.1.5 Discussing factors or objects	Students engage in back and forth dialogues about the objects or factor that they want to include in the model.
Searching	
4.2.1 Seeking information	Students ask teachers, peers or researchers questions about the content knowledge or for modeling ideas.
4.2.2 Gathering resources	Students check their note, search online resources or go to library to gain more information about their project and model.
Synthesizing	
4.3.1 Discussing relationships	Students engage in back and forth dialogues about correlational or cause and effect relationships within their model.
4.3.2 Making connections	Students make connections between factors without specifying certain relationships.
Analyzing	
4.4.1 Deciding about course of action	Students state what they are going to do next.
4.4.2 Recognizing the need of test	Students state their need for test so that they can analyze the model's behavior in test model.
Explaining	
4.5.1 Explaining why/how	Students make explanations of their relationships and/or model behaviors, or provide reasons for including certain factors and objects in the model.
4.5.2 Justifying arguments	Students give examples or state evidence to support their arguments.
4.5.3 Elaborating ideas	Students restate an idea, or provide further information of their ideas.
Evaluating	
4.6.1 Predicting what should happen	Students state what the model should behave before testing it.
4.6.2 Identifying anomalies	Students recognize unexpected findings when testing the model.
4.6.3 Critiquing/interpreting the results	Students make comments on their model behavior in the test mode.
4.6.4 Identifying/proposing solutions	Students suggest what to do in order to fix unexpected findings.
4.6.5 Carrying out solutions	Students actually do their proposed solution.

Table 3

The types of scaffolds and definitions

Scaffold	Definition
Tool	
3.1.1 Sequencing tasks: linear process map	Students have explicit discussions that indicate the linear map of Plan, Build, and Test guide their modeling process.
3.1.2 Factoring functionality: views	Students specifically discuss switching to different view mode to see object setup in the plan mode versus factor setup in the build mode.
3.1.3 Hiding Complexity	Students choose qualitative setup in factor editor or use graphic palette bar to save time.
3.1.4 Facilitating Articulation: Because, description	Student discuss or fill out the “because” statement in relationship editor, or the “description” statement in factor and object editors.
3.1.5 Making context personally relevant: personalize	Students discuss or choose personalized graphic for factor or object.
3.1.6 Linking Multiple Representations	In the relationship editor, students discuss or use the text and graph to decide their relationship. In test mode, when student discuss or use the link between meter and simulation graph.
3.1.7 Manipulate Representations	In test mode, students discuss dynamic feedback while running the simulation.
Teacher	Helps or supports provided by teachers’ or researchers’ statements/behaviors.
3.2.1 Conceptual	Discussion/critique of model structure, problem solving on model function, helping understand factor, objects, relationships and testing.
3.2.2 Utility	Discussion of software function (e.g., how to delete factor, save to web).
3.2.3 Task	Discussion of discrete/immediate actions (e.g., save now, refer to booklets for DO value).
3.2.4 Content	Discussion of declarative knowledge (e.g., the optimum pH is 7, salinity is not measured in pounds).
3.2.5 Strategy	Discussion involving cognitive strategies (e.g., explaining, predicting).
Peer	Helps or supports provided by peers’ statements/behaviors.
3.3.1 Conceptual	Discussion/critique of model structure, problem solving on model function, helping understand factor, objects, relationships and testing.
3.3.2 Utility	Discussion of software function (e.g., how to delete factor, save to web).
3.3.3 Task	Discussion of discrete/immediate actions (e.g., save now, refer to booklets for DO value).
3.3.4 Content	Discussion of declarative knowledge (e.g., the optimum pH is 7, salinity is not measured in pounds).
3.3.5 Strategy	Discussion involving cognitive strategies (e.g., explaining, predicting).

Table 4

The frequency of strategies used in the Plan mode across three sessions in the water quality unit

	Session 1		Session 2		Session 3		Total instances of modeling strategies
Pair	Instances of strategies		Instances of strategies		Instances of strategies		
DA & PA	9 5(4 1 3) 1(4 4 1) 2(4 1 5) 1(4 5 1)		4 1(4 1 1) 1(4 1 5) 1(4 1 3) 1(4 5 1)		Only one very short time at plan mode		26(4 1 3): Identifying object/factor 23(4 1 5): Discussing fac/obj 15(4 4 1): Decide course 7(4 2 1): Seek info. 7(4 5 1): Explain why/h. 3(4 7 1) Exploring 3(4 5 3) Elab. Ideas 3(4 1 1): Generate ideas 2(4 2 2) Gather. Resources 2(4 3 1): Discu. Relation. 1(4 1 2) Stating Goals 1(4 4 2) Reg. The need of test
LM & EB	26 1(4 1 2) 4(4 4 1) 6(4 1 3) 2(4 5 1) 7(4 1 5) 1(4 5 3) 2(4 2 1) 2(4 7 1) 1(4 2 2)		2 2(4 1 3)		No plan mode activities today		
AC & CD	12 2(4 1 1) 1(4 3 1) 4(4 1 3) 3(4 4 1) 2(4 1 5)		1(4 3 2)		Only one very short time in plan mode; students were not so engaged today.		
AT & RN	1 1(4 2 1)		10 2(4 1 1) 1(4 2 1) 4(4 1 3) 1(4 3 1) 1(4 1 5) 1(4 5 1)		2 1(4 1 3) 1(4 4 1)		
KN & WR	10 1(4 1 3) 2(4 4 1) 6(4 1 5) 1(4 5 3)		3 1(4 1 2) 1(4 1 3) 1(4 2 1)		10 3(4 1 3) 1(4 4 2) 3(4 1 5) 1(4 6 4) 1(4 4 1) 1(4 7 1)		
RF & AW	12 2(4 1 3) 3(4 4 1) 1(4 1 5) 2(4 5 1) 2(4 2 1) 1(4 5 3) 1(4 7 1)		N/A		No plan mode activities today		
Summery- Modeling strategies by day	70 2(4 1 1) 1(4 1 2) 18(4 1 3) 18(4 1 5) 5(4 2 1) 1(4 2 2) 1(4 3 1) 13(4 4 1) 5(4 5 1) 3(4 5 3) 3(4 7 1)		19 3(4 1 1) 1(4 1 2) 7(4 1 3) 2(4 1 5) 2(4 2 1) 1(4 3 1) 1(4 3 2) 2(4 5 1)		12 4(4 1 3) 3(4 1 5) 2(4 4 1) 1(4 4 2) 1(4 6 4) 1(4 7 1)		

Table 6

The frequency of strategies used in the Test mode in the water quality unit

	Session 1		Session 2		Session 3		Total instances of modeling
Pair	Instances of strategies		Instances of strategies		Instances of strategies		
LM & EB	No test mode activities today		6		16	1(4 5 1)	34(4 6 3): critiquing/interpreting the results 20(4 6 2) Identifying anomalies 14(4 6 4): identifying/proposing solutions 13(4 2 1): seeking information 12(4 4 1): deciding the course of action 10(4 5 1): explaining why/how 7(4 1 5): Discussing object/factor 6(4 5 3): Elaborating ideas 6(4 3 2): making connections 4(4 3 1): Discussing relationship 3(4 7 1): exploring 2(4 6 1): Predicting what should happen 2(4 6 5): carrying out solutions 1(4 1 2): stating goals
			1(4 1 5)	1(4 4 1)	1(4 1 2)	1(4 5 3)	
			2(4 2 1)	1(4 5 3)	2(4 2 1)	2(4 6 2)	
				1(4 6 3)	1(4 3 2)	4(4 6 3)	
					3(4 4 1)	1(4 6 4)	
DA & PA	1(4 1 5)	5		8	1(4 5 1)		
	1(4 4 1)	2(4 6 3)	1(4 5 1)	3(4 6 2)	1(4 5 3)		
		1(4 1 5)	1(4 6 2)	2(4 6 3)	1(4 6 4)		
AC & CD	4	2(4 6 2)	15		Only stayed in Build mode on time. Not very engaged.		
		2(4 6 3)	5(4 6 4)	3(4 6 2)			
			5(4 6 3)	2(4 3 1)			
AT & RN	10		13		3	1(4 4 1)	
	3(4 2 1)	2(4 7 1)	5(4 6 3)	1(4 4 1)		1(4 6 2)	
	3(4 5 1)	1(4 1 5)	3(4 2 1)	1(4 6 4)		1(4 6 3)	
		1(4 5 3)	2(4 6 2)	1(4 5 1)			
KN&WR	5	1(4 4 1)	18	1(4 5 3)	14		
		1(4 6 2)	1(4 1 5)	2(4 6 2)	1(4 1 5)	1(4 5 3)	
		2(4 6 3)	2(4 2 1)	3(4 6 3)	2(4 3 2)	1(4 6 2)	
		1(4 6 4)	1(4 3 1)	4(4 6 4)	2(4 4 1)	3(4 6 3)	
			1(4 3 2)	2(4 6 5)	1(4 5 1)	1(4 6 4)	
RF& AW	3	1(4 1 5)	N/A		14		
		1(4 3 1)			1(4 2 1)	2(4 5 1)	
		1(4 3 2)			1(4 3 2)	2(4 6 1)	
					2(4 4 1)	2(4 6 2)	
Summery-Modeling strategies by day	24		56		54		
	3(4 1 5)		3(4 1 5)		1(4 1 2)		
	3(4 2 1)		7(4 2 1)		1(4 1 5)		
	1(4 3 1)		3(4 3 1)		3(4 2 1)		
	1(4 3 2)		1(4 3 2)		4(4 3 2)		
	2(4 4 1)		2(4 4 1)		8(4 4 1)		
	3(4 5 1)		2(4 5 1)		5(4 5 1)		
	1(4 5 3)		2(4 5 3)		3(4 5 3)		
	3(4 6 2)		8(4 6 2)		2(4 6 1)		
	4(4 6 3)		16(4 6 3)		9(4 6 2)		
	1(4 6 4)		10(4 6 4)		14(4 6 3)		
	2(4 7 1)		2(4 6 5)		3(4 6 4)		
					1(4 7 1)		

Table 7

Strategies supported by types of scaffolds in the Plan mode in the water quality unit

Scaffolded Strategies								Not Scaffolded
Strategies	Total # of insta.	Tool Scaffolded Code 311-317		Teacher Scaffolded Code 321-325		Peer Scaffolded Code 331-335		
411: Gen. ideas	4	1(3 1 4)		1(3 2 4)		2(3 3 1)		1
412 State goal	0							2
413: ID fac/obj	16	1(3 1 3)	2(3 1 5)	4(3 2 1)		1(3 3 1)		13
		5(3 1 4)	1(3 1 6)	1(3 2 2)		1(3 3 3)		
414 Spe. Rel.:	0							
415: Dis fac/obj	19	5(3 1 4)	1(3 1 6)	6(3 2 1)	2(3 2 3)	1(3 3 2)	1(3 3 4)	7
		1(3 1 5)		1(3 2 2)		1(3 3 3)		
421 Seek info.	5			1(3 2 2)		1(3 3 2)		3
				1(3 2 3)		2(3 3 4)		
422 Gather Res.	1			1(3 2 3)				
431 Dis. Rel.	3	2(3 1 4)				1(3 3 1)		
432 Make conn.	1	1(3 1 2)						
441: Dec. cour.	11	1(3 1 3)		1(3 2 1)		4(3 3 1)		5
		4(3 1 4)		1(3 2 3)				
442 reg. test	2					1(3 3 1)	1(3 3 4)	1
451: Exp. why/h	5	1(3 1 4)		3(3 2 1)		1(3 3 1)		2
452 Justi. arg.:	0							
453 Elab. ideas:	2			2(3 2 1)				1
461 Predict:	0							
462 Iden. anom.	0							
463 Crit.+Inter.	0							
464 Ident. Solu.	0							1
465 Carr. Solu.	0							
471 Exploring	1					1(3 3 1)		3
Summery	70	26 18: facilitating articulation: description 3: Making context Personalized 2: Hidign complexity 2: Linking multiple Representation. 1: factor. func.-view		25 16: tea. scaf. Conce. 5: tea. Scaf. Task 3: tea. Scaf. Util. 1: tea. Scaf. content		19 11: peer scaf. Concep. 4: peer scaf. Content 2: peer scaf. Utility 2: peer scaf. task		39

Table 8

Strategies supported by types of scaffolds in the Build mode in the water quality unit

Strategy	Total # of insta	Scaffolded Strategies			Not Scaffolded
		Tool Scaffolded Code 311-317	Teacher Scaffolded Code 321-325	Peer Scaffolded Code 331-335	
411: Gen. ideas	1			1(3 3 1)	
412 State goal	0				
413: ID fac/obj	5	2(3 1 4)	1(3 2 1) 1(3 2 2)	1(3 3 1)	1
414 Spe. Rel.:	5	2(3 1 4)	1(3 2 1)	2(3 3 1)	8
415: Dis fac/obj	9	1(3 1 3) 2(3 1 4)	4(3 2 1) 1(3 2 2)	1(3 3 1)	1
421 Seek info.	9	1(3 1 3)	2(3 2 1) 1(3 2 3) 3(3 2 2)	2(3 3 4)	3
422 Gather Res.	0				1
431 Dis. Rel.	28	10(3 1 4)	3(3 2 1) 3(3 2 3) 1(3 2 2) 3(3 2 4)	7(3 3 1) 1(3 3 4)	3
432 Make conn.	9	2(3 1 4)	2(3 2 1) 1(3 2 4) 1(3 2 3)	3(3 3 1)	3
441: Dec. cour.	13	1(3 1 3) 3(3 1 4)	2(3 2 1) 1(3 2 3) 1(3 2 2)	2(3 3 1) 1(3 3 3) 2(3 3 2)	4
442 reg. test	0				4
451: Exp. why/h	11		5(3 2 1) 1(3 2 4) 1(3 2 2) 1(3 2 5)	2(3 3 1) 1(3 3 2)	4
452 Justi. arg.:	0				
453 Elab. ideas:	6	1(3 1 4)	3(3 2 1) 2(3 2 2)		
461 Predict:	0				
462 Iden. anom.					
463 Crit.+ Inter.	2	1(3 1 7)		1(3 3 1)	
464 Ident. Solu.	2		1(3 2 3) 1(3 2 4)		
465 Carr. Solu.	3	1(3 1 4)			3
471 Exploring	0				1
Summery	107	24 23(3 1 4) 3(3 1 3) 1(3 1 7)	49 23(3 2 1) 12(3 2 2) 7(3 2 3) 6(3 2 4) 1(3 2 5)	27 20(3 3 1) 3(3 3 2) 1(3 3 3) 3(3 3 4)	36

Table 9

Strategies supported by types of scaffolds in the Test mode in the water quality unit

Strategy	Scaffolded Strategies				Not Scaffolded
	Total # of insta.	Tool Scaffolded Code 311-317	Teacher Scaffolded Code 321-325	Peer Scaffolded Code 331-335	
411: Gen. ideas	0				
412 State goal	0				1
413: ID fac/obj	0				
414 Spe. Rel.:	0				
415: Dis fac/obj	8	1(3 1 7)	4(3 2 1) 1(3 2 2)	1(3 3 1)	
421 Seek info.	12		2(3 2 1) 6(3 2 2)	3(3 2 3) 1(3 2 5)	2
422 Gather Res.	0				
431 Dis. Rel.	3	1(3 1 7)	1(3 2 1) 1(3 2 3)		1
432 Make conn.	4	2(3 1 7)	1(3 2 3) 1(3 2 4)		1
441: Dec. cour.	8	3(3 1 7)	1(3 2 1) 2(3 2 3)	1(3 3 1)	4
442 reg. test	0				
451: Exp. why/h	9		6(3 2 1) 2(3 2 2)	1(3 2 3)	1
452 Justi. arg.:	3		1(3 2 2) 2(3 2 3)		
453 Elab. ideas:	7	1(3 1 7)	4(3 2 1) 2(3 2 3)		
461 Predict:	1			1(3 3 1)	1
462 Iden. anom.	19	1(3 1 4) 1(3 1 6)	10 (3 1 7) 3(3 2 2) 1(3 2 3)	3(3 3 1)	8
463 Crit.+ Inter.	20	4(3 1 6) 7(3 1 7)	4(3 2 1) 1(3 2 3)	2(3 2 4) 2(3 3 1)	14
464 Ident. Solu.	18	1(3 1 4) 4(3 1 6)	9(3 1 7) 1(3 2 3)	3(3 3 1)	3
465 Carr. Solu.	4	3(3 1 7)		1(3 3 1)	
471 Exploring	3		1(3 2 2) 1(3 2 3)	1(3 2 5)	
Summery	119	48	59	12	36
Scaffolds occurred with strategies		37: Manip Repre.. 9:Link Multi. Repre. 2: Because stat.	22: Tea. Scaf. Con. 17: Tea. Scaf. Task 14: Tea. Scaf. Unti. 4: Tea. Scaf. Conte 2: Tea. Scaf. Strat.	12:peer scaff. Concept.	