Taking Stock of Argument: Examining Research Trends in Argumentation in Science Education with Implications for Professional Development

SIBEL ERDURAN
UNIVERSITY OF BRISTOL
UNITED KINGDOM

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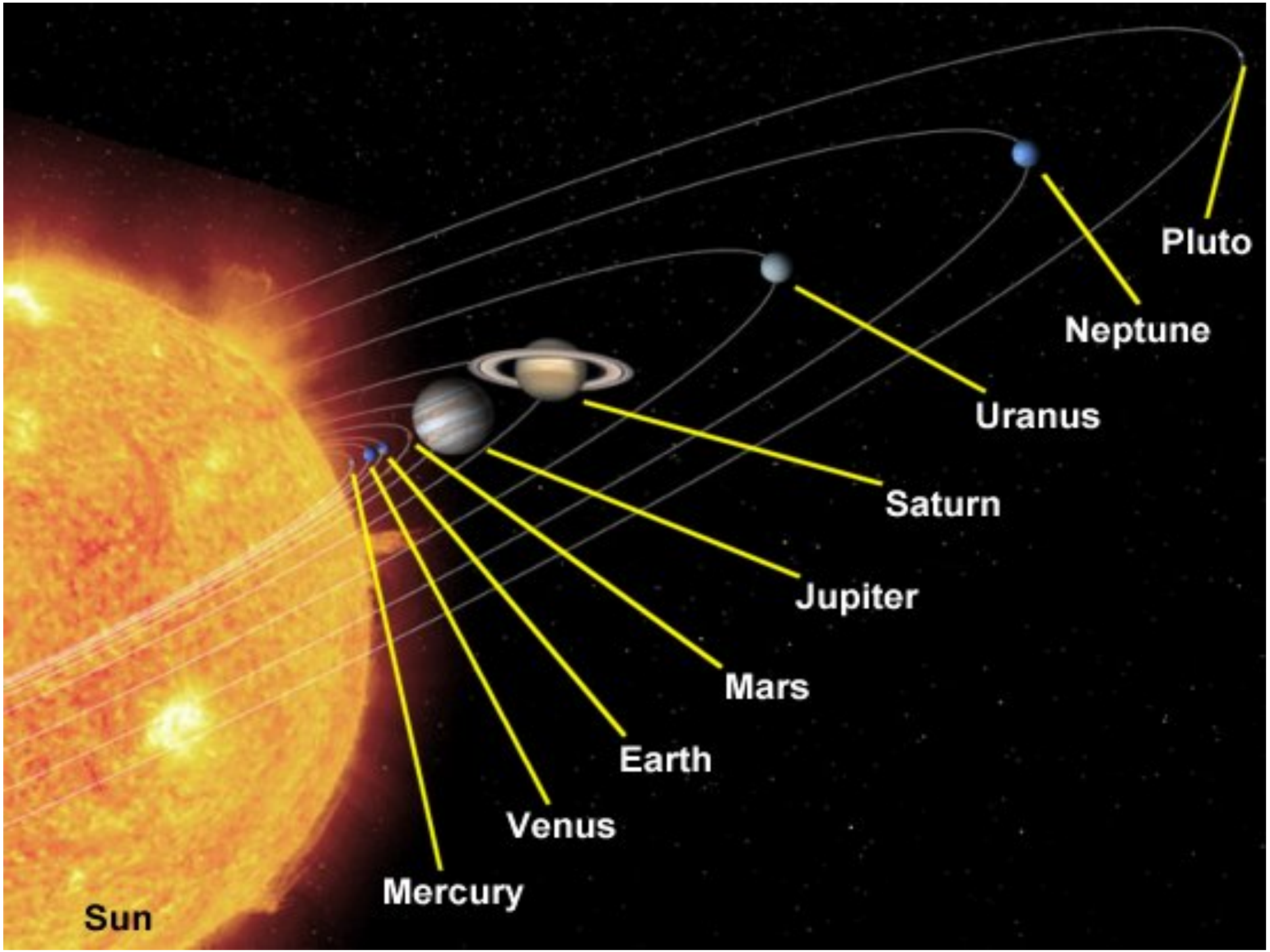
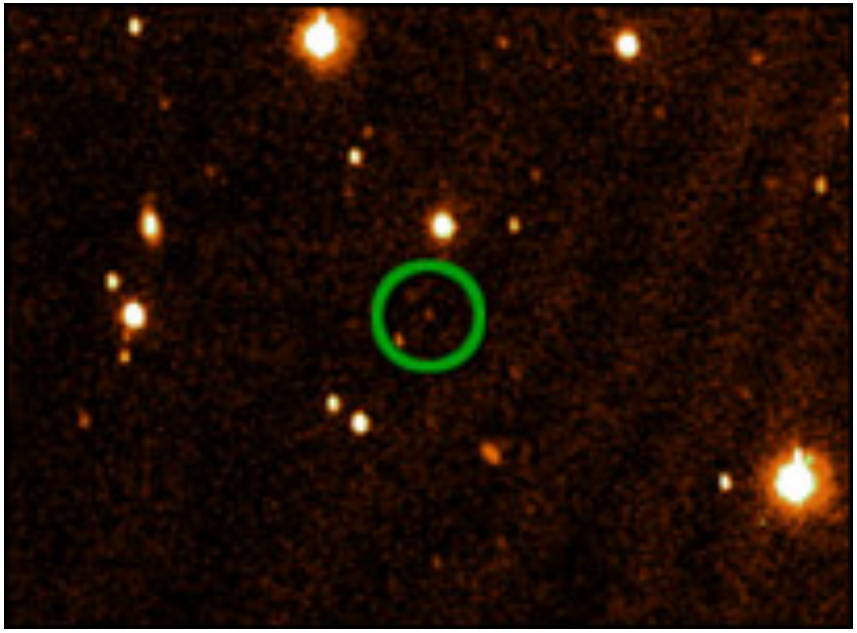
Outline of Presentation

- Recent trends in science education research
- Argumentation as an example
  - Rationale for promoting argumentation in science education
  - Content analysis of top journals to indicate trends
- Modelling argumentation practices in teachers' learning
  - Adoption of Toulmin's model in professional development
  - Impact on teachers' practices
  - Transfer in international contexts and scaling up
- Future agendas
  - Visual data as epistemic objects in argumentation
- Conclusions


Pluto
Neptune
Uranus
Saturn
Jupiter
Mars
Earth
Venus
Mercury
Sun

Tentative Nature of Science?



- *"..observed by astronomers using California's Palomar Observatory, and has been given the name "Sedna" after the Inuit goddess of the ocean. Astronomers now say they have evidence that Sedna has its own moon, although this needs to be confirmed, and is also very red in colour. There is likely to be some debate about whether it qualifies as a true planet, but some scientists are already saying it re-defines our Solar System."*

BBC, 15 March 2004

Educational Research & Policy on Argumentation

- ***Research***
  - **Argument is an important aspect of scientific discourse and practice**
    - (Kelly & Takao, 2002; Kuhn, 1991; Pontecorvo, 1987; Walton, 1996; Zeidler, 2003)
  - **Argument skills critical dimensions of learning and reasoning**
    - (Brown, Collins, Duguid, 1989; Brown & Campione, 1994; Cobb, 1994; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Wertsch, 1991; Kelly & Crawford, 1997; Polman & Pea, 2001).
  - **Argument skills are applicable in everyday contexts** that are demanded of informed citizens particularly in relation to socio-scientific issues (e.g. political, medical, economic decisions)
    - (e.g. Sadler, 2011; Simonneaux, 2008; Zeidler & Sadler, 2008)
- ***Policy***
  - UK – How Science Works, English National Curriculum (2006)
  - USA - Inquiry and the National Science Education Standards (NRC, 2000) Taking Science to School (2007)
  - South Africa - Critical Thinking Skills (Science Curriculum 2005)

Example from PISA Assessment Framework on Interpreting Scientific Evidence & Conclusions

Science Example 2.2

Suppose that on one stretch of narrow road Peter finds that after the lane lines are painted the traffic changes as below.

Speed Traffic moves more quickly

Position Traffic keeps nearer edges of road

Distance apart No change

On the basis of these results it was decided that lane lines should be painted on all narrow roads. Do you think this was the best decision? Give your reasons for agreeing or disagreeing.

Agree: _____
Disagree: _____
Reason: _____

Scoring and comments on Science Example 2.2

Full Credit

Code 1: Answers that agree or disagree with the decision for reasons that are consistent with the given information. For example:

- agree because there is less chance of collisions if the traffic is keeping near the edges of the road, even if it is moving faster;
- agree because if traffic is moving faster, there is less incentive to overtake;
- disagree because if the traffic is moving faster and keeping the same distance apart, this may mean that the drivers don't have enough room to stop in an emergency.

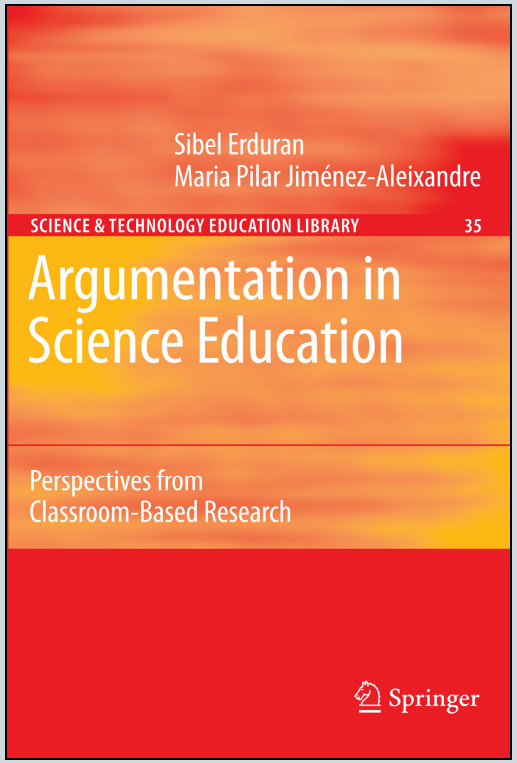
No Credit

Code 0: Answers that agree or disagree without specifying the reasons, or provide reasons unrelated to the problem.

Item type: Open-constructed response
Process: Interpreting scientific evidence and conclusions (Process 3)
Concept: Forces and movement
Situation: Science in technology

(OECD, 2003; p. 144)

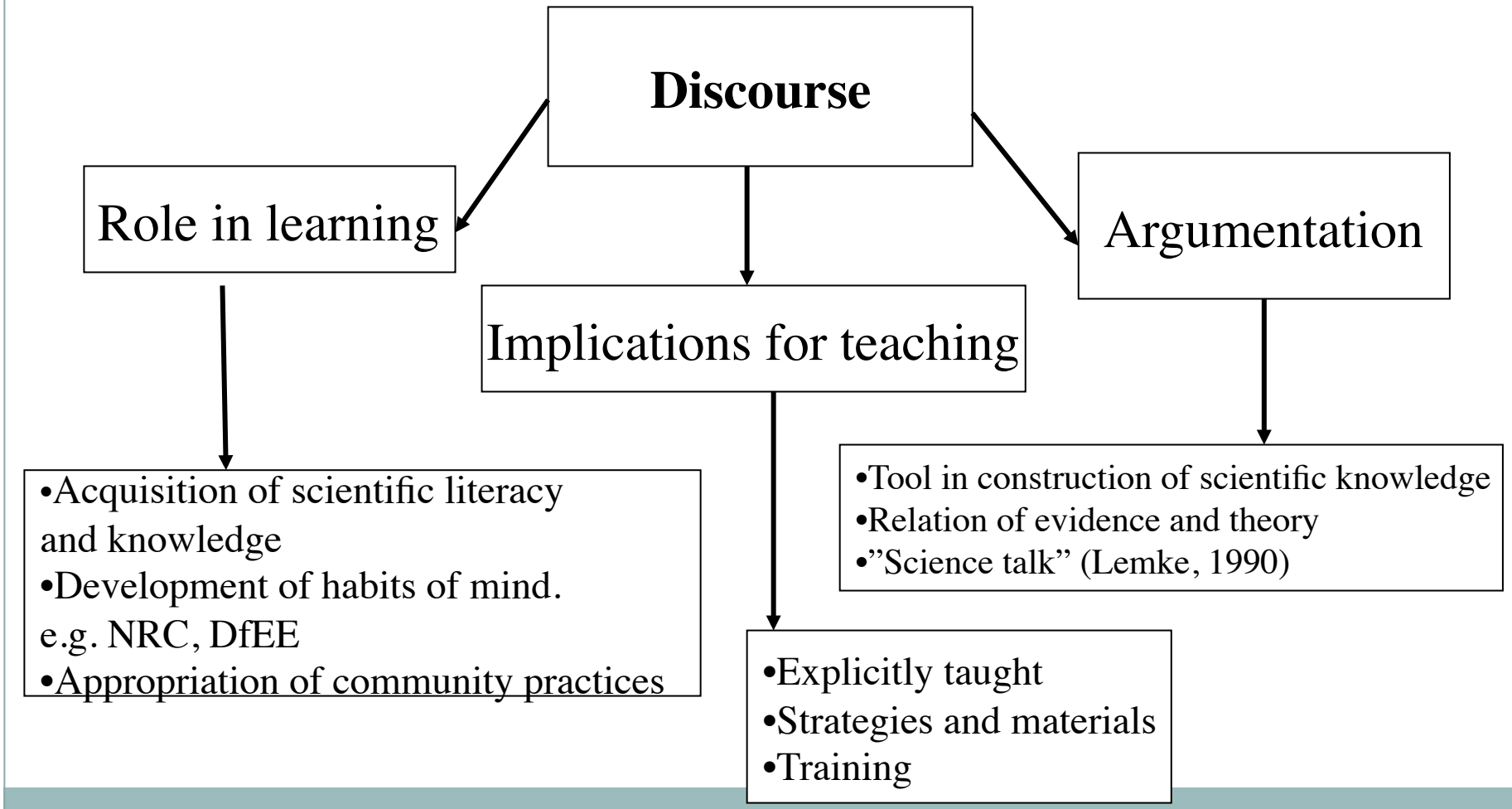
Research in Argumentation in Science Education



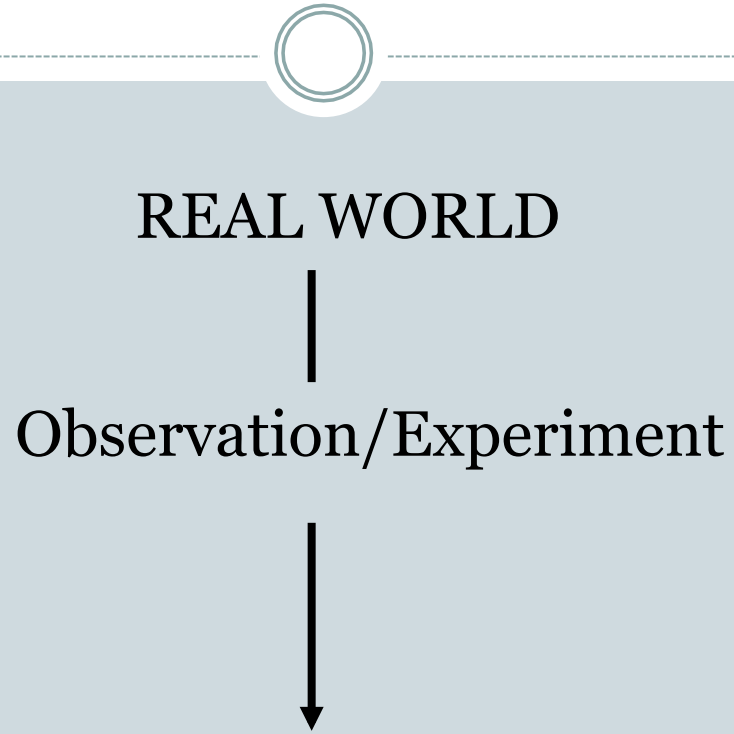
Erduran, S., & Jimenez-Aleixandre, M. P. (2008) (Eds).
Contributors include
Gregory Kelly, Richard Duschl, Dana Zeidler, Andree Tiberghien, Anat Zohar, Laurence Simonneaux, Merce Garcia-Mila, William Sandoval, Douglas Clark, Stein Kolsto, Troy Sadler

Erduran, S., & Jimenez-Aleixandre, M. P. (2011). Argumentation in science education research: perspectives from Europe. In, D. Jorde & J. Dillon (Eds.), *The World of Science Education: Handbook of Research in Europe*. Rotterdam: Sense Publishers.

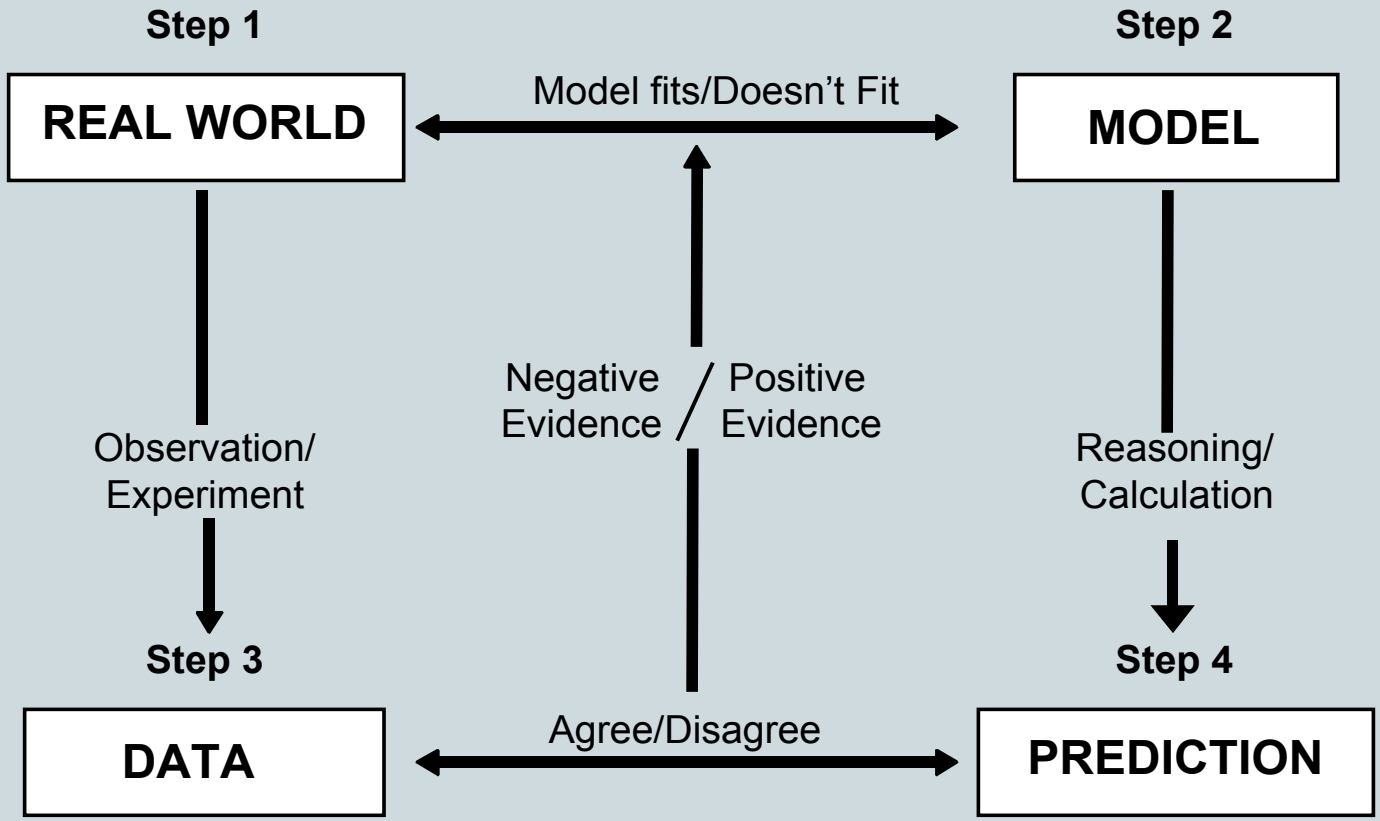
Learning Argumentation



Model of Science Generated by School Science



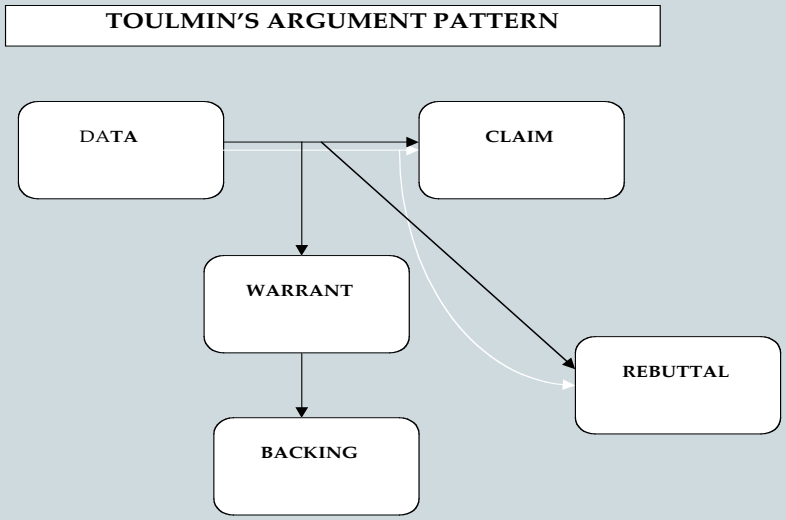
Model of Science
(e.g. Giere, 1991)



Argumentation

Coordination of theory and evidence to justify or refute an explanatory conclusion

Toulmin's Model of Argument (Toulmin, 1958)



Background

- Content analysis of academic journals is an important aspect of educational research (Bowen, 1992; Chang, Chang, & Tseng, 2010; Henson, 2001).
- There are high impact journals such as the *Review of Educational Research* ranked first in the Thompson Reuters Citation Reports that are dedicated to the analysis of research literature.
- Content analysis of journals provides researchers with insight into recent and emerging trends of key themes in the literature.

Lee, Wu & Tsai (2009)

- Science educators have changed some of their research interests during 1998–2007, with a shift in the research topics from student conception learning and conceptual change (1998–2002) to student learning contexts (2003–2007).
- Investigation of highly-cited papers in the past decade revealed that studies on argumentation have gained significant attention among science educators.

Distribution of Research Foci

Table 8. Frequencies and percentages of research topics in individual journals from 2003 to 2007

	IJSE (n = 404)	SE (n = 223)	JRST (n = 242)
Teacher Education	22 (5.4%)	27 (12.1%)	29 (12.0%)
Teaching	64 (15.8%)*	28 (12.6%)	29 (12.0%)
Learning—Conception	70 (17.3%)**	33 (14.8%)**	30 (12.4%)*
Learning—Contexts	106 (26.2%)***	43 (19.3%)***	55 (22.7%)***
Goals, Policy, and Curriculum	46 (11.4%)	33 (14.8%)**	31 (12.8%)**
Culture, Social and Gender	21 (5.2%)	12 (5.4%)	26 (10.7%)
Philosophy, History, and Nature of Science	30 (7.4%)	22 (9.9%)	19 (7.9%)
Educational Technology	26 (6.4%)	6 (2.7%)	15 (6.2%)
Informal Learning	19 (4.7%)	19 (8.5%)	8 (3.3%)

Top one topic***, top two topic**, top three topic*

Highly cited papers

2003–2007	*Title*	*Journal (Year), page.*
1	How literacy in its fundamental sense is central to scientific literacy	*SE* (2003), 224–240.
2	Enhancing the quality of argumentation in school science	*JRST* (2004), 994–1020.
3	Learning to teach argumentation: Research and development in the science classroom	*IJSE* (2006), 235–260.
4	Conceptual change: a powerful framework for improving science teaching and learning	*IJSE* (2003), 671–688.
5	TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse	*SE* (2004), 915–933.
6	Attitudes towards science: a review of the literature and its implications	*IJSE* (2003), 1049–1079.
7	Informal reasoning regarding socioscientific issues: A critical review of research	*JRST* (2004), 513–536.
8	The laboratory in science education: Foundations for the twenty-first century	*SE* (2004), 28–54.
9	Examining the literacy component of science literacy: 25 years of language arts and science research	*IJSE* (2003), 689–725.
10	Patterns of informal reasoning in the context of socioscientific decision making	*JRST* (2005), 112–138.

Country ranks

Table 9. Comparisons of country ranks of publications between 1998–2002 and 2003–2007 (top 10) for the three journals (IJSE, SE, and JRST)

	1998–2002		2003–2007	
Rank	Country	Score	Country	Score
1	USA	346.35	USA	356.82
2	UK	121.76	UK	92.28
3	Australia	69.18	Australia	50.02
4	Canada	37.48	Canada	43.68
5	Israel	29.75	Taiwan	42.04
6	Spain	24.20	Israel	38.64
7	Taiwan	20.40	Spain	28.79
8	South Africa	14.68	Netherlands	21.24
9	Netherlands	14.47	Turkey	16.67
10	Germany	12.08	South Africa	15.16

Trends in Research on Argumentation: Content Analysis of Science Education Journals

(ERDURAN, OZDEM, & PARK, 2011)

Content Analysis of Key Journals

- Four levels of analysis

1st level

Keyword identification & generating systematic categories

A Epistemic aspects of argumentation

B Linguistic and cognitive aspects of argumentation

C Social aspects of argumentation

D Wider epistemic notions related to argumentation

1) Argumentation 2) Argument / argue 3) Claim 4) Evidence based 5) Justification 6) Reasoning	1) Talk 2) Discuss 3) Discourse 4) Conversation 5) Dialogue 6) Negotiation	1) Decision making 2) Shared/sharing meaning making)	1) Inquiry 2) Explain/ explanation

No. of articles from 1998 to 2009 (%)

total number of publications is 2466 and *total number of articles analysed* is 2056

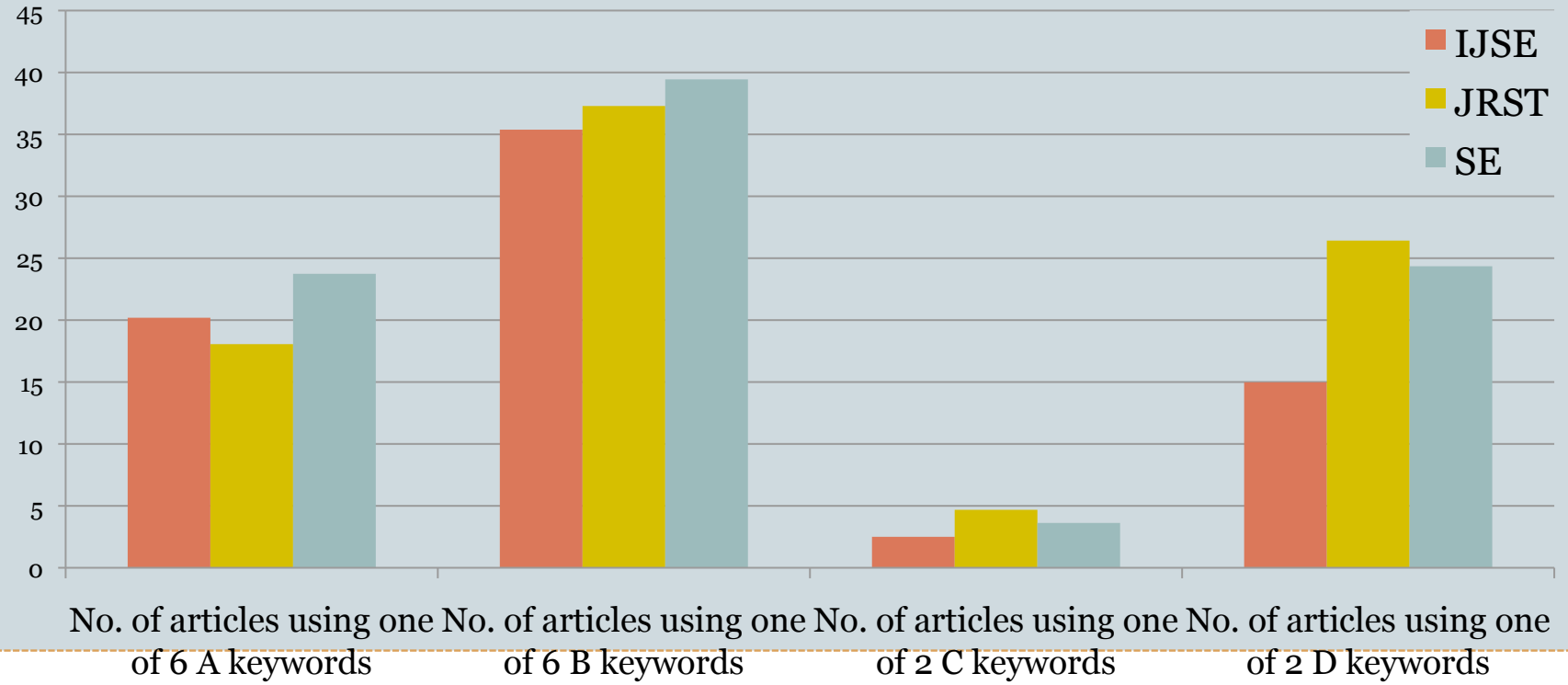
	IJSE		JRST		SE		total	
No. of total published articles from 1998 to 2009	961	(100)	598	(100)	497	(100)	2,056	(100)
No. of non-argumentation-related articles (not including any of 16 keywords)	431	(44.9)	225	(37.6)	176	(35.4)	832	(40.5)
No. of argumentation-related articles using one of 16 keywords	530	(55.2)	373	(62.4)	321	(64.6)	1,224	(59.5)

40% articles from 1998 to 2009 did not include any of 16 keywords at all.

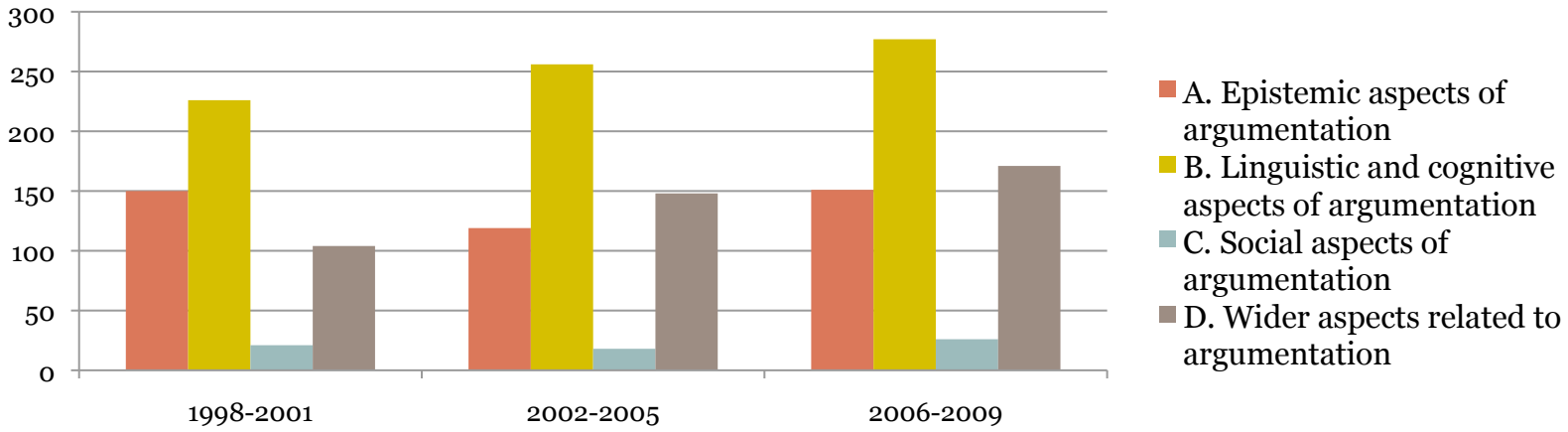
	IJSE		JRST		SE		total	
No. of articles	4	(20.19)	108	(18.06)	118	(23.74)	420	(20.43)
No. of articles using one of 6 B keywords	340	(35.38)	223	(37.29)	196	(39.44)	759	(36.92)
No. of articles using one of 2 C keywords	24	(2.50)	28	(4.68)	18	(3.62)	70	(3.40)
No. of articles using one of 2 D keywords	144	(14.98)	158	(26.42)	121	(24.35)	423	(20.57)

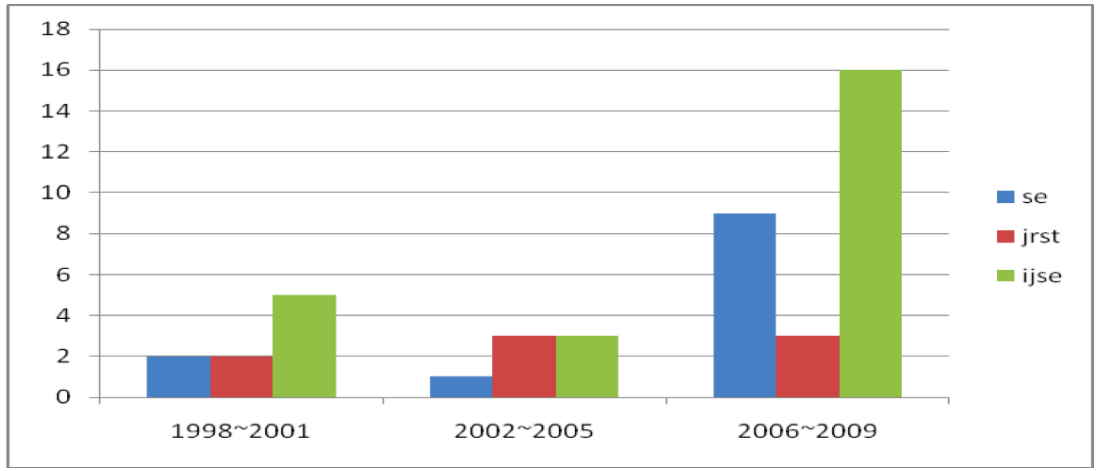
•omitted articles do not have abstract
(editorial, guest editorial, book review, etc) and analysed total of 2056 articles

Distribution of Key Words Across Journals



Distribution by key categories and journal





Trends by Journal across 3- year periods

Argumentation in Science Teacher Education

- Relatively understudied aspect of argumentation studies in science education
- Mainly contextualised relative to other agendas such as learning to teach higher-order thinking skills and critical thinking skills (Zohar, 2008)
- Examples of professional development projects in argumentation in communities of science teachers (Ozdem, Cakiroglu, Ertepinar & Erduran, in press; Simon & Maloney, 2006; Zembal-Saul et al, 2002; 2009)

Professional Development of Teachers

- Supovitz and Turner (2000, p. 964) identify as critical to high-quality professional development the following conditions:
  - immerse participants in inquiry, questioning and experimentation;
  - be intensive and sustained;
  - engage teachers in concrete teaching tasks and be based on teachers' experiences with students;
  - focus on subject-matter knowledge and deepen teachers' content skills;
  - be grounded in a common set of professional development standards and show teachers how to connect their work to specific standards; and
  - be connected to other aspects of school change.

Principles of Continuous Professional Development

- **Distributed expertise and peer-mentoring** provide the structure and support for teachers to learn with and from each other – can be a team of teachers from different stages in their careers
- **Teachers as researchers** situate teachers at the centre of their own learning, investigating problems and devising solutions to their teaching and learning needs – teachers identified their own issues and the means to address them
- **Reflective enquiries into teaching** promote learning based on concrete examples of teaching and meta-cognitive awareness of own pedagogical content knowledge – teacher reflectivity enhanced by the use of video and peer feedback
- **Collaborative planning, teaching and reflection** facilitates teachers' learning through communication and sharing of the knowledge and skills required of teaching – a team of teachers was set up and given time resources to share knowledge and work collaboratively
- **Evidence-based teaching** engages teachers in the modes of thinking and acting that promote understanding of syntactic knowledge of science, and provide rationale for decisions about teaching and learning – the university-school partnership provided instruments for gathering evidence and a forum for developing such evidence-based thinking.

Teacher Knowledge

- Subject matter knowledge
  - Substantive knowledge (explanatory structures and paradigms of the field)
  - Syntactic knowledge (procedures and methods through by which new knowledge is created in the field)
  - Content knowledge (facts and concepts)
- Pedagogical content knowledge
  - Blend of pedagogical knowledge and subject matter knowledge specific to teaching topic

(Lee Shulman, 1986)

Meta-Knowledge

- Meta-strategic knowledge (MSK)
  - Metal-level knowledge of thinking skills
  - General knowledge about cognitive structures being manipulated
- Epistemological meta-knowing (EMK)
  - Way individuals conceptualise knowledge and knowing

(Zohar et al., 2009)

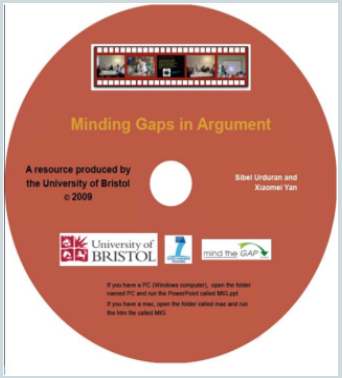
Funded Projects

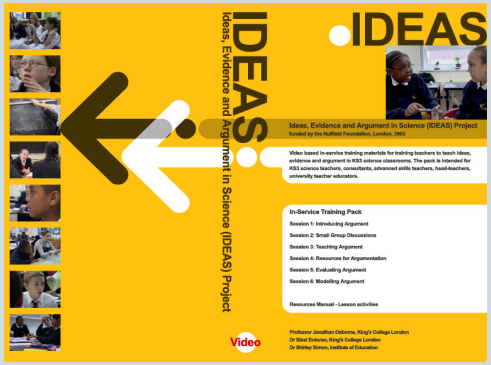
- Enhancing the Quality of Argumentation in School Science (ESRC) - 1999-2002
- Ideas, Evidence and Argument in Science Education (Nuffield) - 2002-2003
- Continuing Professional Development in Argumentation (Gatsby) - 2003-2004
- Ideas and Evidence in Initial Teacher Training (Key Stage 3 Strategy) – 2004
- Step-IN (Training and Development Agency for Schools) – 2005-2006
- Catalan and English Elementary Teachers' Argumentation (Anglo-Catalan Society, 2006-2008)
- Fostering Evidence-Based Science Teaching (2007-2008)
- Mind the Gap in Inquiry-Based Science Teaching (European Union) – 2008-2010
- Science Teaching Advanced Methods (European Union) – 2009-2012

Example Foci

- In-Service Teacher Training in England
  - (e.g. Erduran, Ingram & Yee, 2011; Erduran & Yan, 2010; Erduran, Simon & Osborne, 2004)
- Pre-service Teacher Training in England and Turkey
  - England (e.g. Erduran, 2006) and Turkey (Erduran, Ardac & Yakmaci-Guzel, 2007; Ozdem, Cakiroglu, Ertepinar & Erduran, in press)
- Elementary science teachers in comparative contexts, Spain and England
  - (Castells, Erduran & Konstantinidou, 2009)

Professional Development Resources





Sound Travels

OHT 4.3

- **Through Solids**
- **Through Liquids**
- **Through Gases**

Michael is sitting in a boat in the ocean. The boat has a metal hull. He is hammering the bottom of the boat.

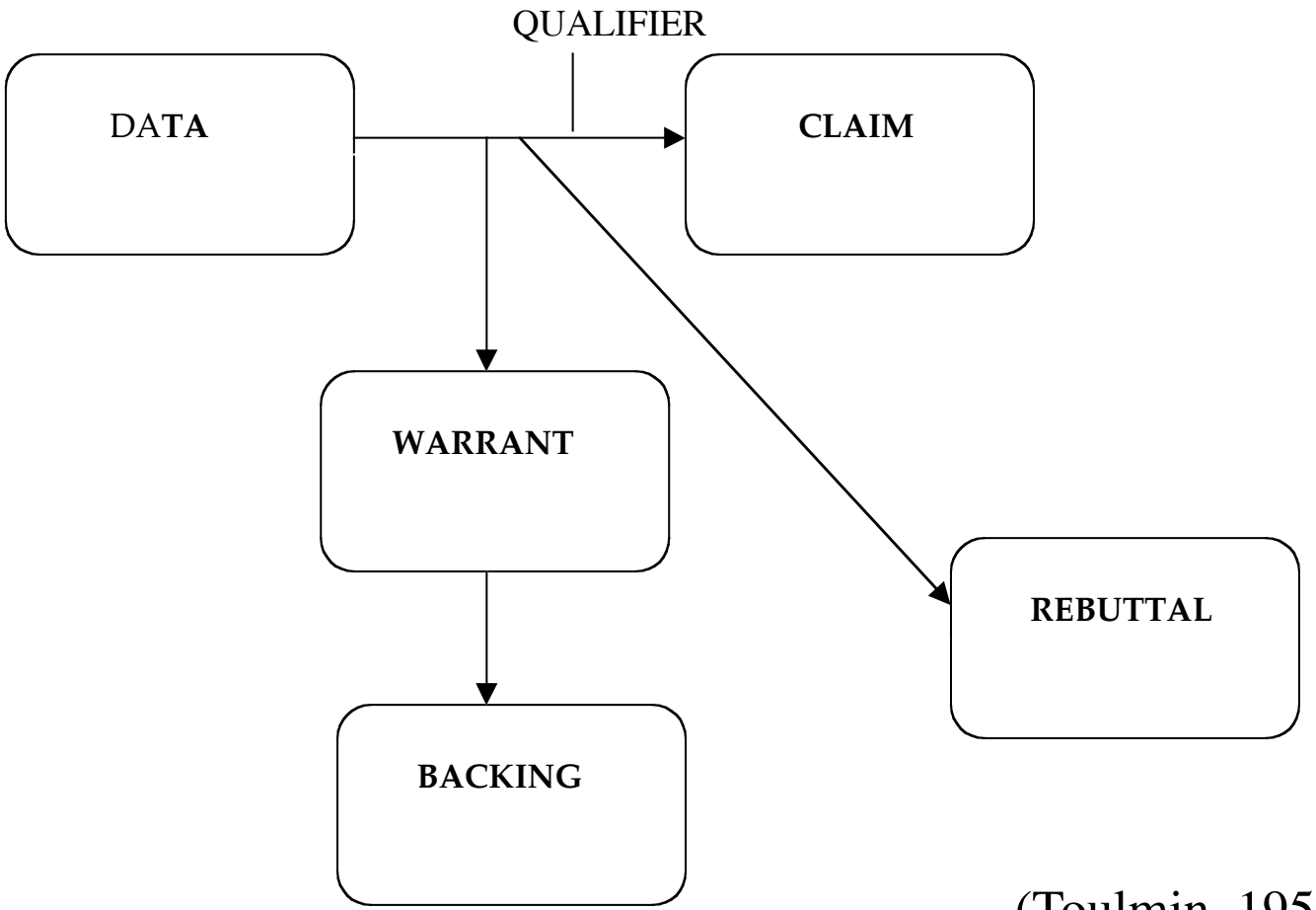
Will Nicola or Naseem hear the sound of the hammering first? Or will they hear it at the same time?

Use the evidence on Handout 4.8 to make your case.

Writing Frame Example

- My idea is…
- My reasons are that…
- I believe my reasons because…
- Ideas against my idea are…
- I would convince someone who doesn't believe me by…

TOULMIN'S ARGUMENT PATTERN



(Toulmin, 1958)

Pedagogical strategies

- Materials for student activities
- Arguing prompts
- Role-play
- Writing frames
- Group presentations

Arguing Prompts

- Why do you think that?
- What is your reason for that?
- Can you think of another argument for your view?
- Can you think of an argument against your view?
- How do you know?
- What is your evidence?
- Is there another argument for what you believe?

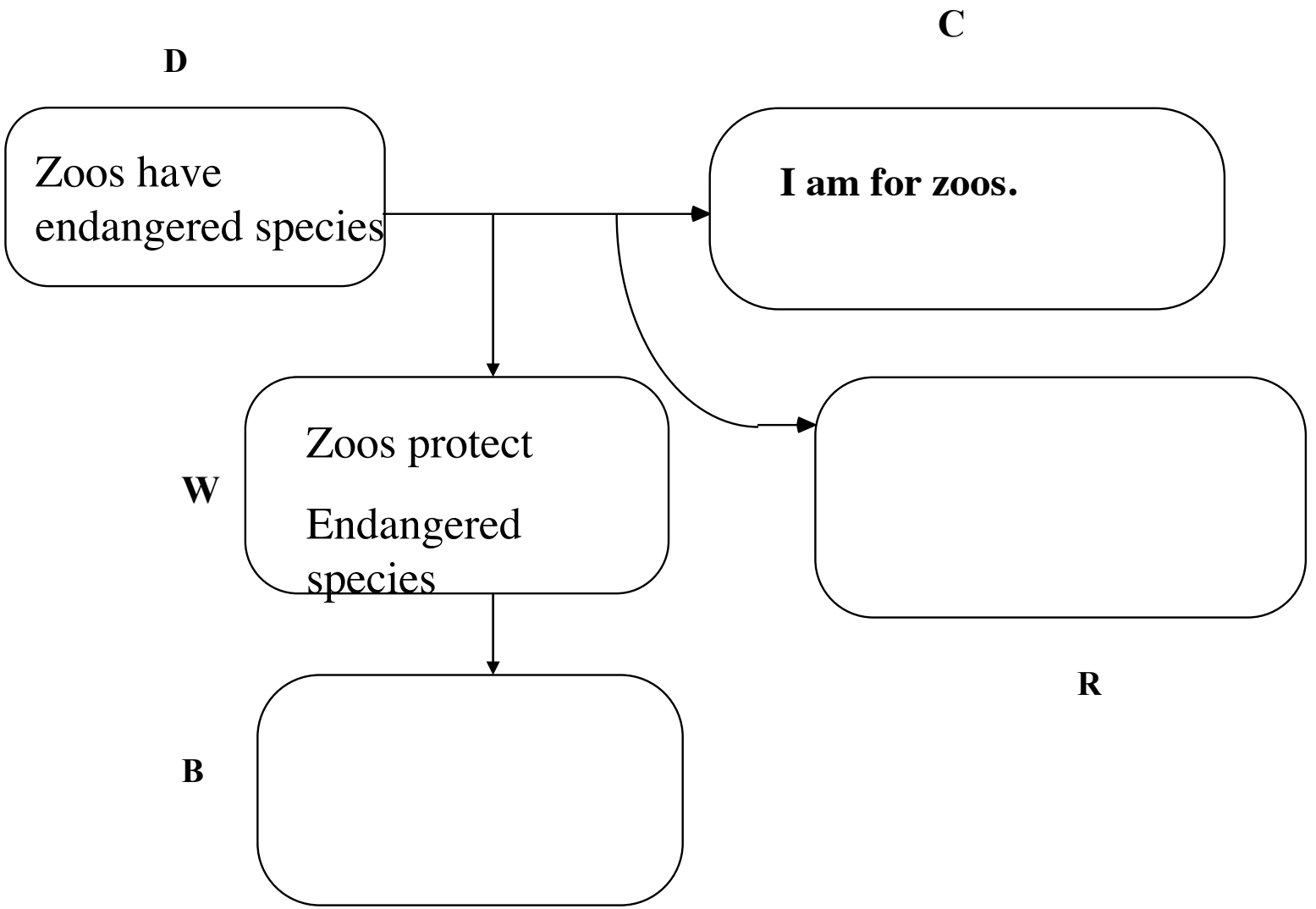
Toulmin's Argument Pattern (TAP)

- Example including claim, data, warrant:

T Yeah. Can you think of any others for?

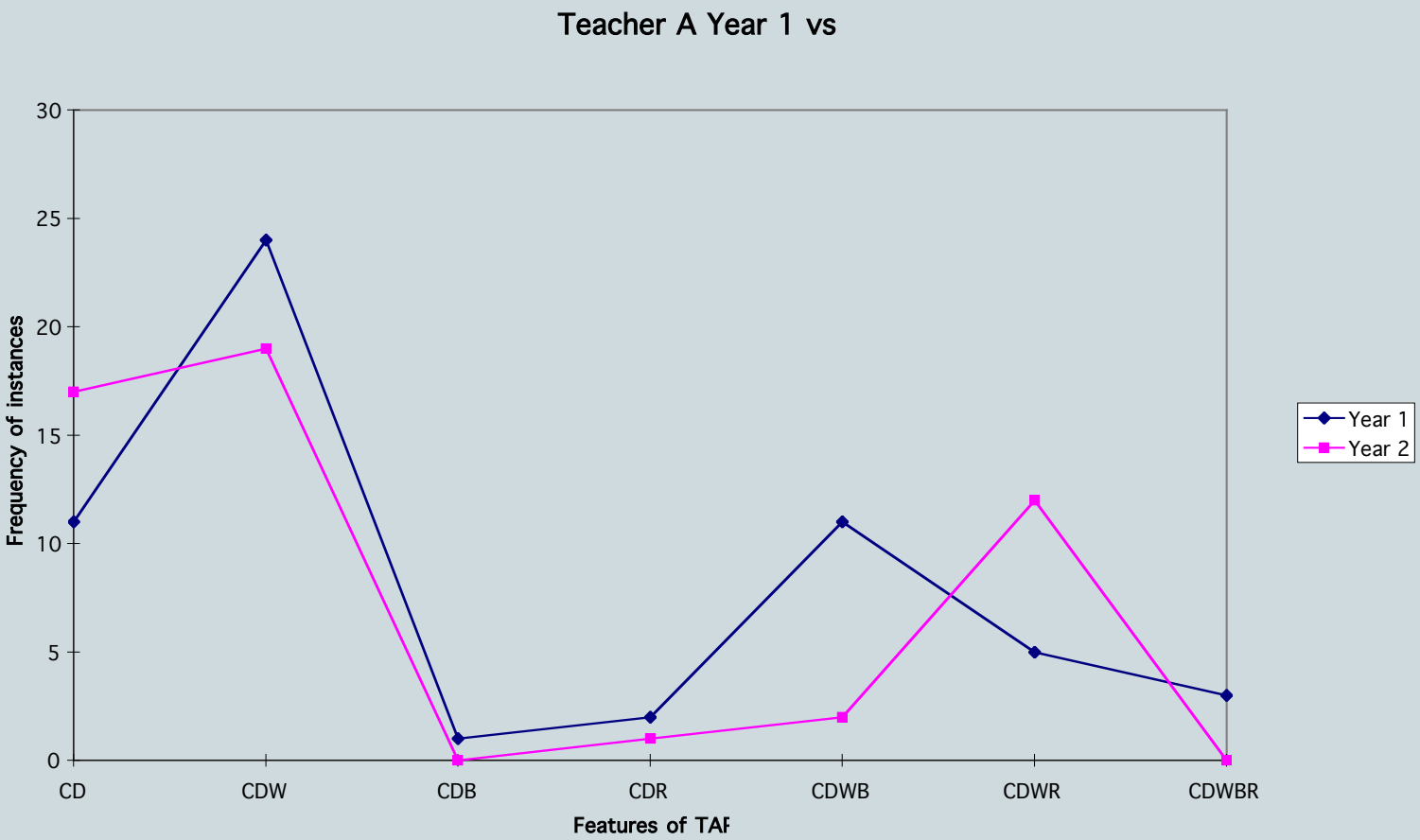
S The zoo has like endangered species

T Yes, if they are becoming extinct or endangered then it becomes a way of protecting endangered species doesn't it?

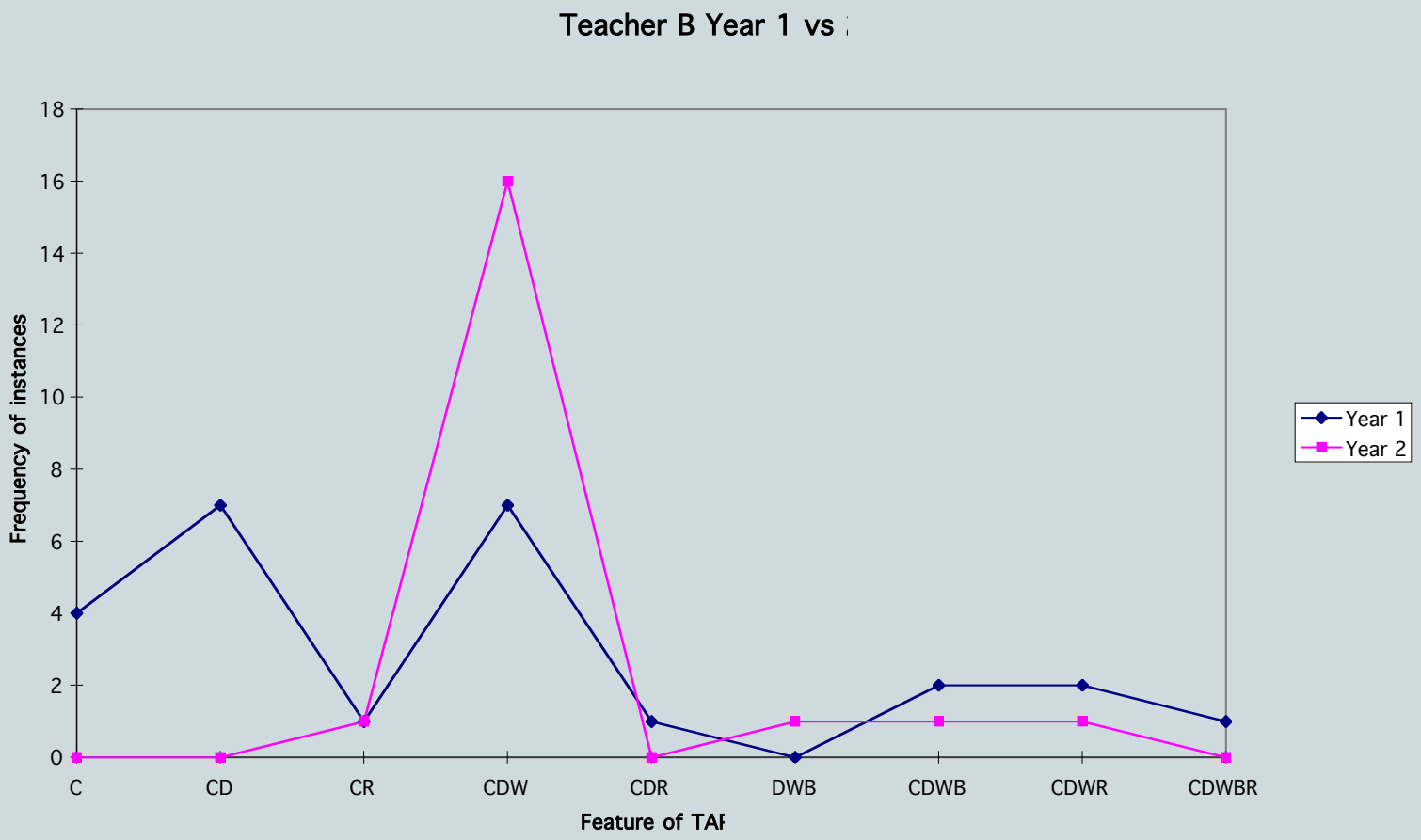

C
D
Zoos have endangered species
I am for zoos.
Zoos protect
Endangered species
W
R
B

Teacher	Year	CD, CR	CDW, CDR	CDWR, CDWB	CDWBR	Sig
Jeremy+	Year 1	48	47	5	0	
	Year 2	59	27	14	0	*
Peter	Year 1	41	47	10	2	
	Year 2	23	31	38	8	**
Maureen	Year 1	36	43	21	0	
	Year 2	43	43	14	0	
Frances+	Year 1	33	9	49	9	
	Year 2	52	3	42	3	*
Jules	Year 1	0	82	18	0	
	Year 2	8	44	44	4	**
Patrick	Year 1	48	38	14	0	
	Year 2	25	57	16	2	**
Mary+	Year 1	20	70	10	0	
	Year 2	0	50	50	0	**
Annie+	Year 1	48	32	16	4	
	Year 2	5	85	10	0	**
Sarah+	Year 1	21	68	11	0	
	Year 2	28	31	41	0	**
Katie	Year 1	32	47	16	5	
	Year 2	38	43	19	0	
Jason	Year 1	36	48	16	0	
	Year 2	41	41	14	4	
Matthew	Year 1	31	57	12	0	
	Year 2	46	42	12	0	

Teacher A


Teacher A Year 1 vs
30
25
20
15
10
5
0
Frequency of instances
CD
CDW
CDB
CDR
CDWB
CDWR
CDWBR
Features of TAF
Year 1
Year 2

Teacher B


Teacher B Year 1 vs
Frequency of instances
18
16
14
12
10
8
6
4
2
0
C
CD
CR
CDW
CDR
DWB
CDWB
CDWR
CDWBR
Feature of TAI
Year 1
Year 2

Levels of Argument

Level 1: **Level 1 arguments are arguments that are a simple claim v a counter claim or a claim v claim**

Level 2: **Level 2 arguments consist of claims with either warrants, backings or data but do not contain any rebuttals.**

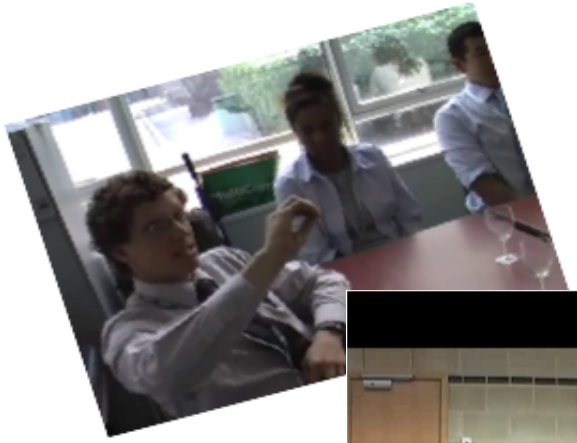
Level 3: **Level 3 arguments consist of a series of claims or counter claims with either data, warrants or backings with the occasional weak rebuttal.**

Level 4: **Level 4 arguments consist of a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter claims as well but this is not necessary.**

Level 5: **This is an extended argument with more than one rebuttal.**

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: developments in the use of Toulmin's Argument Pattern for studying science discourse. *Science Education*, 88(6), pp.915-933.

Modelling Argumentation Practices



- Identifying a problem to investigate
  - Negotiating and justifying choice of topic, pupils etc.
- Gathering and evaluating data
  - School-based work including peer video-taping and pair conversations on data
- Selecting and justifying evidence
  - Group selection of video and resource data
- Communicating knowledge
  - Workshop presentations to peers; conference presentation by team

Modelling Argumentation Practices

- Identifying a problem to investigate
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Identifying a problem to investigate

T1: We've had a theme, a goal. We knew what we were striving for and I think that's very important for your professional development. If you know what the end product, the objective is, much like the kids really, then you can drive yourself to the end. I often feel with professional development days, sessions, it's very waffly and you have no idea. You feel, that wasn't personalised for me. I think what this project has done is it made it personal for each one of us.

T2: *That comes from the fact that we chose what we were going to do. In terms of a brief, it was a very open brief. You said pick some classes about inclusion. To be honest, we were a bit like…right! What do we do now? Then we sort of discussed what classes we shared together. We asked what do we do together? So that was the initial collaboration to begin with.*

T1: *What concerns do we have.*

T2: *What problems do we have? We discussed our classes and suddenly it started fitting in together because we came up with it not, because we were prescribed with something to do.*

Data gathering and interpretation:

Counter-claim & appeal to data

- T1: You know it's…It didn't flow as well as I hoped it would. The barriers to talking seemed to still be there.
- T2: Uhm, I don't, I don't know whether I agree coz having gone around and spoken to them, uhm, on an individual group by group basis…
- T1: Yeah.
- T2: …each group was very happy to tell me on camera…
- T1: Yes.
- T2:… what they were doing and who was doing what and their strengths and all that kind of thing within the group, so they obviously had it worked out.

Selecting and justifying evidence:

Pedagogical goals and outcomes

- T4: At least it shows how they use, that, that we did get them to use ICT eh?
- T2: Yeah, I think, it's fine to show that they are using IT…
- T3: Right, let's get the clip with Sam
- T4: …coz we did say about that didn't we?
- T3: …sort of looking at…

Selecting and justifying evidence:

Engagement with target learner

- T3: Do you want that or not?
- T2: You can if you want, it mentions the fact that George's name is up there. This goes so quick
- T3: Clip 12, yeah.

Nature of CPD

- *It has kind of opened up our eyes to the fact that professional development obviously isn't just going out on a course. Like professional development is something that you can do for yourself if you're given the time. So for example, you know for us we feel our professional development has stemmed from us working together and pulling ideas from each other and exploiting if you like everybody's strong points.* (Learning Support Teacher)

Scaling up

S-TEAM
FIRING UP SCIENCE EDUCATION

- 25 institutions across Europe, funded by EU
- Teachers leading professional development workshops
- www.apisa.co.uk

Future Agendas for Argumentation

- Conventional emphasis on analysis of textual and verbal communication
- Increasing interest in not only text but also a wide range of visual representations in understanding scientific practices
- Production of scientific knowledge, of techniques of representation, and of practices of production of meaning.
- Visual representations as epistemic objects

(Knorr-Cetina, 2001)

Context

- Renewed theoretical interest in the concept of practice (Schatzki, Knorr Cetina & von Savigny 2001).
- Focusing on actual working practices of scientists and knowledge practices on artifacts (Rheinberger, 1997)
- Visual representations as artifacts of knowing (Latour, 1986)

Visual Information

- Embody a wide range of knowledge, extending from science-specific knowledge (Vincenti, 1990) to aesthetic knowledge (Ewenstein & Whyte, 2004)
- Allow professionals with different perspectives to make sense of and contribute to the new knowledge (Eckert & Boujut 2003)

Epistemic Objects

- Ways of embodying knowledge and assisting knowing are part of what allows us to see visual representations as "epistemic objects."

- Central characteristic of epistemic objects, as identified by Knorr Cetina (1997; 2001), is their openness, their "lack in completeness of being" and their "capacity to unfold indefinitely" (Knorr Cetina 2001, p. 181)

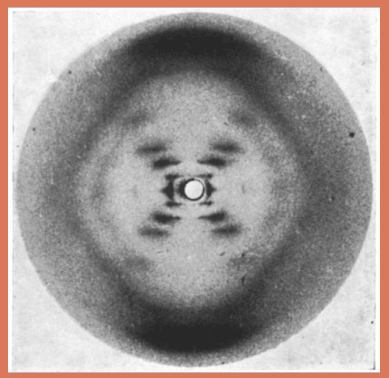
Visual Representations as Epistemic Objects

- Study of production, representation and appropriation of visual information;
- Making of visual standards in the production, evaluation and communication of visual data;
- Blurring the distinctions between the making and communication of scientific knowledge

(Pauwels, 2006)

Case Study

Visual data as evidence



- *"...since the middle of the summer Rosy [Rosalind Franklin] had had evidence for a new three-dimensional form of DNA. It occurred when the DNA molecules were surrounded by a large amount of water. When I asked what the pattern was like, Maurice went into the adjacent room to pick up a print of the new form they called the "B" structure. The instant I saw the picture, my mouth fell open and my pulse began to race. The pattern was unbelievably simpler than those previously obtained (A form). Moreover,* ***the black cross of reflections which dominated the picture could arise only from a helical structure****. With the A form the argument for the helix was never straightforward, and considerable ambiguity existed as to exactly which type of helical symmetry was present. With the B form however, mere inspection of its X-ray picture gave several of the vital helical parameters"* (Watson, 1968, pp. 167-169).

Conclusions

- Argumentation as an important aspect of epistemic practices of science and science education research
- Design of professional development for modeling argumentation practices
- Future work in positioning the role of visual representations in argumentation
- Enriching the epistemic landscape of science education