Designing for Productive Failure

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1

What is Productive Failure?

Understand what students know about a novel concept that they have not been taught yet

Afford opportunities to activate and differentiate prior and intuitive knowledge….to generate, explore, critique, and refine representations and solution methods (RSMs) for solving complex problems

Invariably, such a process leads to failure (in relation to a desired goal)…

Designing for failure in the initial learning to minimize failure in the longer term…

But, this may precisely be the locus of deep learning… provided some form of structure follows subsequently

2

Two phases of the PF design

(Kapur & Bielaczyc, 2012)

GENERATION & EXPLORATION	CONSOLIDATION & KNOWLEDGE ASSEMBLY
PHASE I	**PHASE II**
Complex problems Collaboration Affective support for persistence	Consolidation Well-structured Problem solving OR Instruction OR Feedback OR Explanation, etc.

DELAY OF STRUCTURE

3

The Problem

(Grade 8/9 students)

Who's the most consistent striker?

Year	Mike Arwen	Dave Backhand	Ivan Right
1988	14	13	13
1989	9	9	18
1990	14	16	15
1991	10	14	10
1992	15	10	16
1993	11	11	10
1994	15	13	17
1995	11	14	10
1996	16	15	12
1997	12	19	14
1998	16	14	19
1999	12	12	14
2000	17	15	18
2001	13	14	9
2002	17	17	10

4

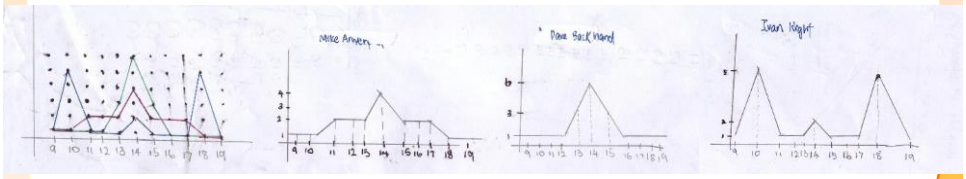
Comparing regularity

	9	10	11	12	13	14	15	16	17	18	19
Mike Arwen	1	1	2	2	2	4	2	2	2	1	1
Dave Backhand	1	1	1	1	3	6	3	1	1	1	1
Ivan Right	1	5	1	1	1	2	1	1	1	5	1

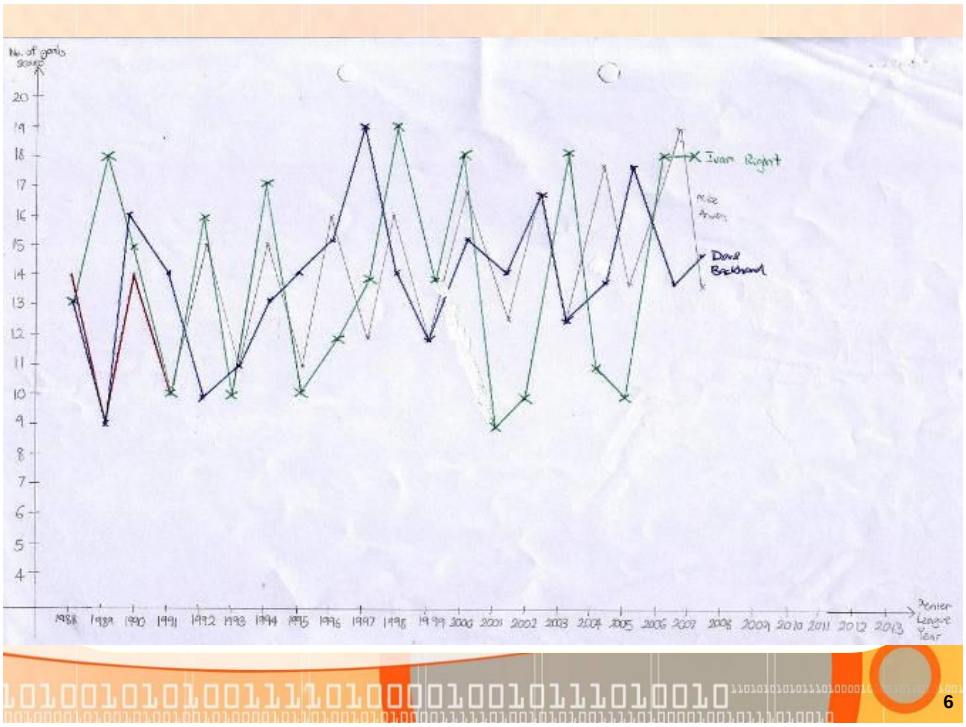
Mike Arwen: Mean = $\frac{280}{20}$ = 14 goals / year; Mode = 14

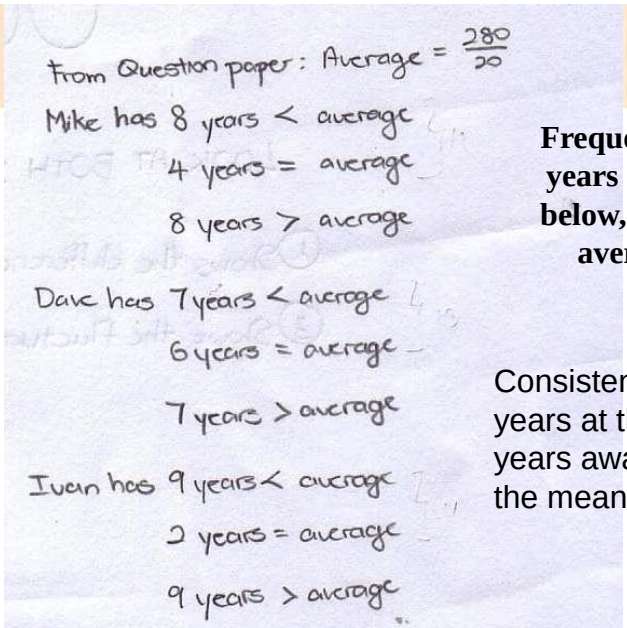
Dave Backhand: Mean = $\frac{280}{20}$ = 14 goals / year; Mode = 14

Ivan Right: Mean = $\frac{280}{20}$ = 14 goals / year; Mode = 18 and 10



9 10 11 11 12 12 13 13 14 14 14 14 15 15 16 16 17 17 18 19



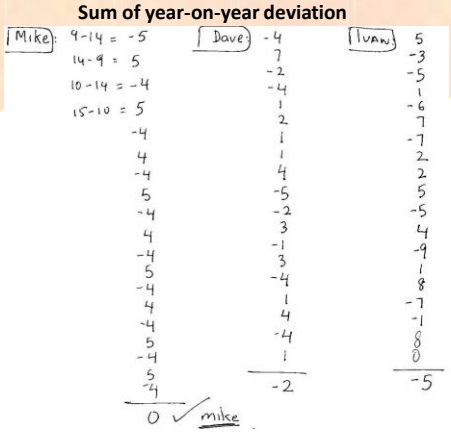


Frequency of years above, below, and at average

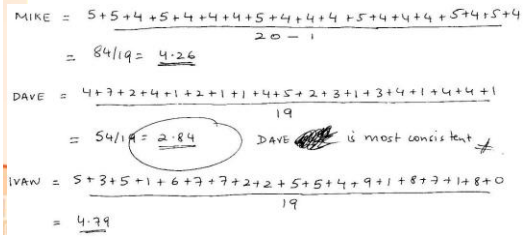
Consistency = years at the mean / years away from the mean

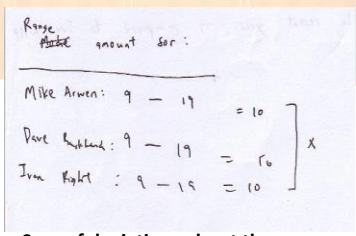
7

Sum of year-on-year deviation

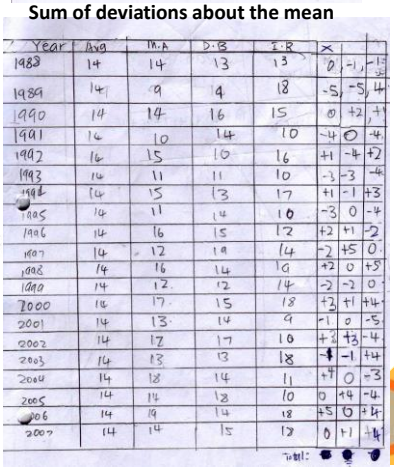


Average of year-on-year absolute deviation





Sum of deviations about the mean



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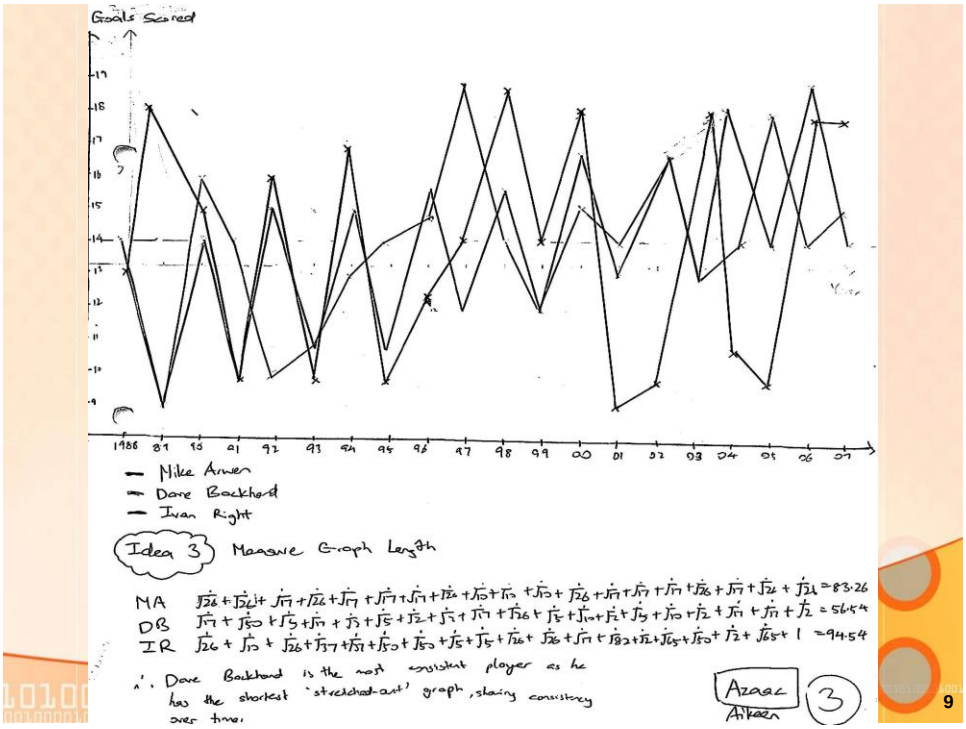


Productive Failure vs. Direct Instruction

Target Concepts:
1. Average Speed (Kapur, 2010; Kapur & Bielaczyc, 2012)
2. Standard Deviation (Kapur, 2012)

Productive Failure Students generate multiple representations and solution methods, followed by instruction

Direct Instruction Teacher explains concept, models problem solving, uses worked-out examples, practice and feedback

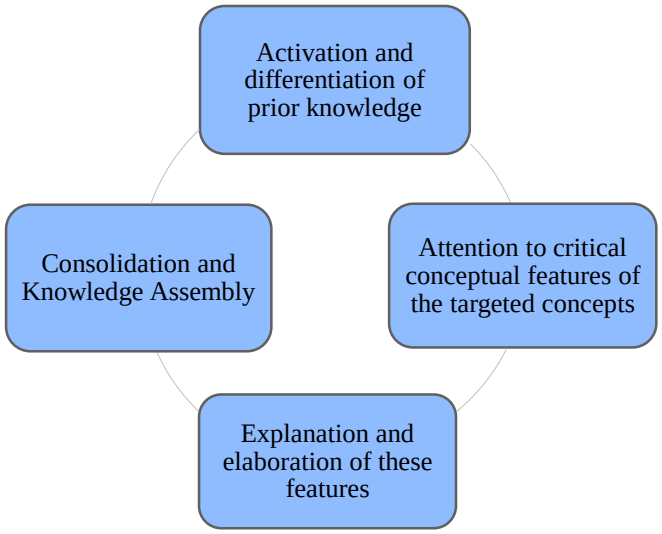
Dependent Variables:
1) Procedural Fluency
2) Conceptual Understanding
3) Transfer

Summary of Key Findings

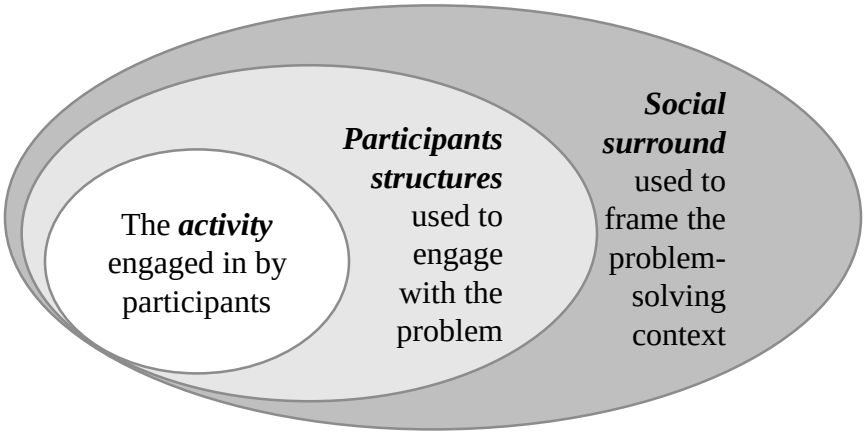
- PF outperformed DI on conceptual understanding and transfer without compromising procedural fluency (Kapur, 2010, 2012; Kapur & Bielaczyc, 2012)
- Students that seem strikingly dissimilar on general and math ability (PSLE) appear strikingly similar in terms of their generative capacity (Kapur & Bielaczyc, 2012)
- RSM diversity significantly correlated with learning gains (Kapur, 2012; Kapur & Bielaczyc, 2012)
- Teachers consistently underestimate students' ability to generate RSMs
- PF teachers consistently report that they are stressed and stretched to work with students' ideas… BUT, they themselves understood the math better…

Four mechanisms of the PF design

(Kapur & Bielaczyc, 2012)



Three layers of the PF design
(Kapur & Bielaczyc, 2012)



7

Designing for Productive Failure
(Kapur & Bielaczyc, 2012)

	DESIGN LAYERS AND THE EMBODIED PRINCIPLES		
DESIGN PHASES	**TASK**	**PARTICIPATION STRUCTURES**	**SOCIAL SURROUND**
1. Generate and explore multiple representations and solutions methods (RSMs)	Design tasks that are adequately complex, engaging, and draw on students' mathematical resources	Enable collaboration to allow students to elaborate, critique, explain, and evaluate shared work, thereby further enriching the shared representation and solution spaces	Create a safe space for students to explore and generate by setting appropriate socio-mathematical norms, and providing affective support for persistence
2. Organization and Knowledge Assembly	Compare and contrast student-generated and canonical ideas	Enable student engagement through group presentations and students' participation; teachers act as facilitators, paraphrasing student explanations, and drawing attention to critical features	Create a safe space to explore the affordances and constraints of student-generated RSMs with a view of improving upon them, and not assessing them as correct or incorrect

8

Productive Failure Tasks

Targeted Concepts	Targeted Levels
Average Speed	Secondary (7th grade)
Standard Deviation	Secondary (7th, 8th, 9th grade)
Central Tendencies	Secondary (7th grade)
Normalization	Pre-University 2 (11th grade)
Hypothesis Testing	Pre-University 3 (12th grade)
Fractions	Primary (3rd grade)

15

Central Tendencies
(Grade 7 students)

Which number represents each class?

Amount of weekly pocket money students from 1A received ($)	Amount of weekly pocket money students from 1B received ($)	Amount of weekly pocket money students from 1C received ($)		Amount of weekly pocket money students from 1D received ($)
10	10	10	15	10
11	11	11	16	11
12	12	12	16	12
13	12	13	16	13
14	12	14	16	13
14	13	14	16	13
15	14	14	17	14
15	15	14	18	15
15	16	14	19	16
16	17	15	20	17
16	18	15		18
17	18	15		19
18	18	15		19
19	19	15		20
20	20	15		30

16

Standard Deviation
(Grade 7/8/9 students)

Who's the most consistent striker?

Premier League Year	Mike Arwen	Dave Backhand	Ivan Right
2001	14	13	17
2002	11	11	14
2003	15	14	16
2004	12	16	11
2005	16	14	12
2006	12	12	16
2007	16	14	12
2008	13	15	16
2009	17	14	12
2010	14	17	13
2011	14	14	15

Normalization
(Grade 11 students)

Who's the most outstanding performer?

Scores of Math Students between 1998 and 2012	Scores of Science students between 1998 and 2012	Scores of English Students between 1998 and 2012
72	71	72
73	72	72
74	80	75
75	80	75
75	81	78
75	81	78
81	81	81
81	81	81
81	81	84
87	81	84
87	81	87
87	82	87
88	82	90
89	**90** (Lisa, top science student, 2012)	**90** (David, top English student, 2012)
90 (Firdaus, top math student, 2012)	91	

Hypothesis Testing
(Grade 12 students)

Which student's sample is least likely to come from Wala Chocolate Factory?

Net weight: 50 grams each chocolate bar

Weights of chocolate bars bought by Ahmad (g)	Weights of chocolate bars bought by Bella (g)	Weights of chocolate bars bought by Charles (g)	Weights of chocolate bars bought by Devi (g)
58	64	64	75
55	61	63	74
54	60	60	74
49	55	54	73
49	55	54	73
49	55	54	73
48	54	48	55
48	54	45	55
48	54	44	55
48	54		55
47	53		37
47	53		37
47	53		37
42	48		36
41	47		36
38	44		35