Productive Failure

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Motivations

- 19/20\textsuperscript{th} Century Application to 21\textsuperscript{st} Century Design contexts
- Focus on initial learning
- Using failure deliberately - Unguided design
- Scaffolding and timing of learning resources
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)...

But, this may precisely be the locus of deep learning... provided some form of structure follows subsequently
Designing for Productive Failure
(Kapur & Bielaczyc, 2012)

PHASE I
- Complex problems
- Collaboration
- Affective support for persistence

PHASE II
- Consolidation
- Well-structured
- Problem solving OR
- Instruction OR
- Feedback OR
- Explanation, etc.

DELAY OF STRUCTURE
The Problem
(Grade 8/9 students)

Who’s the most consistent striker?

<table>
<thead>
<tr>
<th>Year</th>
<th>Mike Arwen</th>
<th>Dave Backhand</th>
<th>Ivan Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>14</td>
<td>13</td>
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<td>1989</td>
<td>9</td>
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<td>1990</td>
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<td>2002</td>
<td>17</td>
<td>17</td>
<td>10</td>
</tr>
<tr>
<td>Comparing Regularity</td>
<td>9</td>
<td>10</td>
<td>11</td>
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<tr>
<td><strong>Mike Arwen</strong></td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mean = ( \frac{280}{20} ) \quad = 14 goals/year</td>
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<tr>
<td>Mode = 14</td>
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<tr>
<td><strong>Dave Backhand</strong></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mean = ( \frac{280}{20} ) \quad = 14 goals/year</td>
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<tr>
<td>Mode = 14</td>
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<tr>
<td><strong>Ivan Right</strong></td>
<td>1</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Mean = ( \frac{280}{20} ) \quad = 14 goals/year</td>
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<tr>
<td>Mode = 18 and 10</td>
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</tbody>
</table>

**Graphs**

- **Mike Arwen**
- **Dave Backhand**
- **Ivan Right**
From Question paper: Average = \( \frac{280}{20} \)

Mike has 8 years < average
4 years = average
8 years > average

Dave has 7 years < average
6 years = average
7 years > average

Ivan has 9 years < average
2 years = average
9 years > average

Frequency of years above, below, and at average

Consistency = years at the mean / years away from the mean
Sum of deviations about the mean

Average of year-on-year absolute deviation

Mike: 9 - 14 = -5
14 - 9 = 5
10 - 14 = -4
15 - 10 = 5
-4
-4
-5
-4
-4
-4
-4
-4
-4
-2
3
-1
-3
-4
-1
1
-5
0
\[ \text{MIKE} = \frac{5 + 5 + 4 + 5 + 4 + 4 + 5 + 4 + 4 + 5 + 4 + 4 + 5 + 4 + 4 + 5 + 4 + 4}{20} = \frac{84}{19} = 4.42 \]

Dave: 7 - 14 = -7
-2
-4
-5
-4
-5
-4
-1
1
-7
0
\[ \text{DAVE} = \frac{4 + 7 + 2 + 4 + 1 + 2 + 1 + 1 + 4 + 5 + 2 + 3 + 1 + 3 + 4 + 1 + 4 + 4 + 1}{19} = \frac{54}{19} = 2.84 \]

Ivan: 5 - 14 = -9
2
-4
-5
-4
-5
-4
-1
1
-8
0
\[ \text{IVAN} = \frac{5 + 3 + 5 + 1 + 6 + 3 + 7 + 2 + 2 + 5 + 5 + 4 + 9 + 1 + 8 + 7 + 1 + 8 + 0}{19} = 4.79 \]

Range amount for:
Mike Arwen: 9 - 14 = 10
Dave Beadle: 9 - 19 = 10
Ivan Fright: 9 - 15 = 10

Sum of year-on-year deviation

\[ \text{MIKE} = -4 \]
\[ \text{Dave} = 7 \]
\[ \text{Ivan} = 5 \]

Range: 
Mike Arwen: 9 - 14 = 10
Dave Beadle: 9 - 19 = 10
Ivan Fright: 9 - 15 = 10
Goals Scored

Year

1988 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05

= Mike Amer
= Dave Backlund
= Ivan Right

Idea 3: Measure Graph Length

MA \frac{5}{26} + \frac{5}{52} + \frac{5}{7} + \frac{5}{12} + \frac{5}{13} + \frac{5}{26} + \frac{5}{37} + \frac{5}{7} + \frac{5}{26} + \frac{5}{26} + \frac{5}{7} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} = 83.26

DB \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} = 56.54

IR \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} + \frac{5}{26} = 94.54

Dave Backlund is the most consistent player as he has the shortest stretched-out graph, showing consistency over time.
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

![Diagram](image)

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

![Diagram](image)

**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)
- The marginal gain of providing cognitive support for PF groups during the generation phase was not significant (Kapur, 2011)
- Teachers consistently underestimate students’ ability to generate RSMs
- 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)
- PF teachers consistently report that they are stressed and stretched to work with students’ ideas... BUT, they themselves understood the math better...
Explaining Productive Failure

- Activation and differentiation of prior knowledge
- Attention to critical features
- Critiquing, explaining, elaborating
- Owning...want to see the canonical solution
- Becoming flexible and adaptive
- Learning about math and what math is about
Implementation Issues

1. Student readiness – learning vs. development
2. Teacher Knowledge: CK, PCK, Design Knowledge
3. Teacher beliefs
4. School-level factors
   - Leadership support
   - Timescale of embodied, sustainable change
   - Integration into work, not add-on
   - Personnel movement
5. System-level issues
   - High-stakes assessment
   - Cultural factors – ambiguity, argumentation, failure
   - Parental pressures
   - From learning packages for mass deployment to principled design-based expertise development...