

RESPONSIVE TEACHING

COGNITIVE SCIENCE AND
FORMATIVE ASSESSMENT
IN PRACTICE

HARRY FLETCHER-WOOD



A David Fulton Book

First published 2018
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

and by Routledge
711 Third Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

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British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data

Names: Fletcher-Wood, Harry, author.

Title: Responsive teaching : cognitive science and formative assessment
in practice / Harry Fletcher-Wood.

Description: Abingdon, Oxon ; New York, NY : Routledge, [2018] | Includes
bibliographical references and index.

Identifiers: LCCN 2017060136 (print) | LCCN 2018014627 (ebook) |

ISBN 9781315099699 (ebook) | ISBN 9781138296879 (hbk) |

ISBN 9781138296893 (pbk) | ISBN 9781315099699 (ebk)

Subjects: LCSH: Effective teaching. | Cognitive learning. | Lesson planning. |
Educational tests and measurements.

Classification: LCC LB1025.3 (ebook) | LCC LB1025.3 .F59 2018 (print) |

DDC 371.102-dc23

LC record available at <https://lccn.loc.gov/2017060136>

ISBN: 978-1-138-29687-9 (hbk)

ISBN: 978-1-138-29689-3 (pbk)

ISBN: 978-1-315-09969-9 (ebk)

Typeset in Interstate
by Apex CoVantage, LLC



Printed and bound in Great Britain by
TJ International Ltd, Padstow, Cornwall

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Students struggle to identify what success looks like.

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? The problem

Students struggle to identify what success looks like.

Anne has a clear purpose and objective, but she is struggling to help her students write coherently. They write willingly, using the language structures Anne teaches, but Anne finds their work is leaden where it should be light; imitative where it should be original. Today, Emma's piece is at the top of the pile of marking. Anne steals a glance, then places it carefully at the bottom: Emma *gets* good writing. She takes the structures Anne teaches and transforms them into original pieces which really work; today, Anne asked students to create a feeling of dread; Emma's piece makes Anne shiver. Can this be taught, or is Emma just a born writer? Anne wonders:

- How can she show students what success looks like, and how can it be achieved?



The evidence

Sharing a sense of how to create success is challenging; examples are critical
 Demonstrating what success looks like helps all students, especially low attainers
 Knowing what success looks like promotes metacognition and motivation

Anne's students must know what success looks like if they are to achieve it. Clear, challenging goals improve performance, directing attention, increasing persistence and arousing relevant knowledge; they increase people's belief they can do well and their motivation to conduct a task (Locke and Latham, 2002). Yet distant goals do not mobilise effort, direct action or support gauging self-efficacy; big tasks need to be broken into "attainable subgoals" which provide "immediate incentives and guides for action" (Bandura, 1982, p. 134; Bandura and Schunk, 1981). Anne needs to share clear, immediate goals: a vision of success. This is echoed by research in deliberate practice, which suggests that it

both produces and depends on effective mental representations. Mental representations make it possible to monitor how one is doing, both in practice and in actual performance. They show the right way to do something and allow one to notice when doing something wrong and to correct it.

(Ericsson and Pool, 2016, pp. 99-100)

Conveying what success looks like to create these mental representations is challenging, however. Teachers often struggle to describe

exactly what they are looking (or hoping for), although they may have little difficulty in recognizing a fine performance when they see one . . . Teachers' conceptions of quality are typically held, largely in unarticulated form, inside their heads as tacit knowledge.

(Sadler, 1989, p. 126)

Concrete descriptors, like 'include quotations', 'label the axes' and 'use arms for balance' can help students follow procedures. They cannot convey the quality of what is to be achieved, however. 'Support your argument', 'be ambitious' and 'approach the task methodically' say little; if students knew how to be 'methodical', they would. So, such descriptors can "lead to frustration because of their inflexibility" (Sadler, 1989, p. 134); students' work may meet the criteria but still fail to reach the desired standard. Concrete descriptors do not reflect underlying, implicit strengths of student work (Hammond, 2014). They cannot articulate the tacit (Rust, Price and O'Donovan, 2003): an idea "which cannot be specified in detail cannot be transmitted by prescription, since no prescription for it exists. It can be passed on only by example from master to apprentice" (Polanyi, 1962, p. 53). Students' sense for success is "'caught' through experience" (Sadler, 1989, p. 135): the acquisition of an "arsenal of exemplars" (Kuhn, 2001, cited in Christodoulou, 2017, p. 96). Ideally, these exemplars should be examined by the student alongside an expert. Historically this was done by individual tutors, yet Anne must find a way to share a sense of success with her entire class (Sadler, 1989; Rust, Price and

O'Donovan, 2003). Anne cannot tell students what success looks like; she needs to find a way to show them.

- **Anne realises that a list of criteria helps students check aspects of their work, but does not convey the sense of quality she wants them to gain; this requires sharing model work.**

Anne finds that research in cognitive science has identified two approaches to help students recognise and achieve success.

1) The worked example effect

Studying models - worked examples - has a powerful impact on the quality of student work (Kalyuga and Sweller, 2004; Sweller, van Merriënboer and Paas, 1998; Wittwer and Renkl, 2010). Students who have seen model work seem to learn better and more efficiently (Zhu and Simon, 1987), an effect which has been demonstrated for tasks with clear solutions (like maths problems) and those with a range of solutions (like English essays; (Kyun, Kalyuga and Sweller, 2013)), and is being extended to behaviours like cooperation and subjects like art (Renkl, Hilbert and Schworm, 2009). Successful learning from worked examples "does not always occur naturally however" (Wittwer and Renkl, 2010, p. 394); students may not engage with them (Sweller, van Merriënboer and Paas, 1998).

2) The completion problem effect

A powerful variation of the worked example effect engages students in what success looks like by offering partially completed models and asking students to complete the missing steps. Checking whether students know the next step also provides a rapid test of prior knowledge (Kalyuga and Sweller, 2004). This seems to decrease extraneous cognitive load, helping students to create mental models and transfer their learning to new problems (Sweller, van Merriënboer and Paas, 1998).

Anne looks to introduce worked examples and completion problems within teaching sequences. 'Interleaving' seems particularly effective, alternating between showing worked examples and asking students to solve problems (Pashler et al., 2007). Teachers' explanations seem to add little or nothing to students' understanding of examples (underscoring the challenge of conveying success in words); having students explain the merits of a model themselves may be sufficient (Renkl, Hilbert and Schworm, 2009; Wittwer and Renkl, 2010). What matters is students' thoughtful engagement with the models.

- **Anne resolves to:**
 - **Use worked examples**
 - **Use completion problems**
 - **Interleave models with problems for students to solve**

Clarifying what success looks like seems to benefit all students, but particularly those with low prior attainment. Students with low prior knowledge of a topic benefit from worked examples; those with high prior knowledge can solve problems with limited guidance (Kal-yuga and Sweller, 2004; Sweller et al., 2003). Students with low prior attainment struggle with ambiguous goals. For example, higher-attaining students in maths recognise that $1+2$ is a procedure ($1+2$) and a concept (all the ways in which 3 can be reached); lower-attaining students see it as a procedure alone. In consequence,

the more able recognise that the process of addition first taught is not the main aim of the game and go on to succeed. The less able who try to do what they are asked: to master the counting procedure, seem cheated because when they finally do so, the game has moved on to a more advanced stage and left them behind.

(Gray and Tall, 1994, p. 19)

Overcoming ambiguity by showing what success looks like seems to particularly benefit lower-attaining students. Students who were shown how their work would be assessed, and evaluated their and their peers' work, gained more factual and conceptual knowledge and greater skill in inquiry design than students with the same teacher who were not shown how their work would be assessed. Students with low prior attainment benefited most; the gains "actually enhance" their learning "without impeding the high achieving students" (White and Frederiksen, p. 91). Anne realises that sharing what success looks like has great promise for the students who most need her help.

Additionally, Anne learns that sharing what success looks like seems to support student metacognition and increase motivation. Metacognition - students monitoring their learning and adapting accordingly - seems to have powerful effects on learning, particularly for lower-achieving and older students (Casselman and Atwood, 2017; Koriati, 2007; Ericsson and Pool, 2016; Zimmerman, 2002). Student self-monitoring relies on accurate self-assessment: the student coming "to know what constitutes quality" (Sadler, 1989, p. 126) and how their work compares to it. Helping students to self-assess accurately and plan accordingly has powerful effects on learning (Casselman and Atwood, 2017; White and Frederiksen, 1998). Knowing what success looks like is also motivating. White and Frederiksen (1998) found that students with low prior attainment were prone to submitting duplicate projects (copying their partners' work), but in the group shown what success looked like, this "tendency was nearly eliminated" (p. 37). This seems to be a strong basis for independent learning and collaboration; when Anne sees Sixth Form students collaborating, she realises this is because several years of learning the subject has shown them what success looks like, thus allowing effective collaboration.

- Anne hopes that sharing what success looks like will encourage students and improve their metacognition.



The principle

Responsive teachers show students what success looks like



Practical tools

Share model work of different standards
Help students identify what makes work great

Anne wants to:

- Share models which show students how to succeed in their tasks.
- Support students to identify what about those models matters.
- Help students use these examples to improve their own work.

Version 1

Anne has formulated clear objectives for the lesson (Problem 2), and she tries using these to share success criteria with students. She considers involving students by having them suggest learning objectives, rewrite objectives in their own words or guess missing words from the objectives. Anne notes a significant limitation, however: students might state the goal ('Write more elegantly') or they might state how it will be achieved ('Choose more specific verbs'), but this offers no guarantee they will be able to pick better verbs while writing. So Anne tells students the lesson's objective, sometimes through direct statements ('This lesson we're going to learn to multiply fractions'), sometimes by showing a problem students will be able to complete by the end and sometimes by providing introductory stimulus material such as an unexpected image and helping students frame worthwhile questions (Phillips, 2001). Sometimes, Anne asks students to recall the objectives and link them to the current activity. Sharing the objectives seems motivating and worthwhile; she wants students to know the goal of each lesson. She recognises, however, that this does nothing to show what success looks like; she needs to introduce students to model work.

Version 2

Lessons and units build towards work which encapsulates the learning: a good sentence, solution or essay; Anne wants students to know how to complete them well. She considers sharing the mark scheme with students, going through the descriptors together or rewriting them collectively to clarify what she's looking for. She begins writing success criteria:

- Use rhetorical questions.
- Give your opinions.

Anne's experience is that lists like this encourage students to use rhetorical questions frequently and carelessly, however. Lists are helpful for improving some aspects of students' work - checking decimal points and capital letters, for example - but she wants students to understand when a rhetorical question will work. Anne has been trying to describe good writing, to convey tacit ideas in words, and has been failing. Offering further description when her first description did not work seems unhelpful, while providing increasingly specific

criteria about how students are to respond will constrain their writing severely. Anne notes that mark schemes often lack ambition and are unhelpful in showing what matters (Hammond, 2014; Massey, 2016). Only one success criterion counts: is it good? For persuasive writing, for example: 'Did your writing prove persuasive?' In maths: 'Is this a clear, accurate solution?' The challenge is sharing the ingredients of persuasion and clarity with students without resorting to a focus on mechanical features. Raking over descriptions of success seems less helpful than examining examples.

Version 3

Anne is inspired by Ron Berger, who describes how examples "set the standards for what I and my students aspire to achieve" (2003, pp. 29-30). Berger offers students "a taste of excellence" (p. 31) using models by former students and videos of them presenting their work, alongside models from other schools and from the professional world. Carolyn Massey demonstrates historical writing by examining the work of historians such as Orlando Figes (2016). Anne identifies an excellent answer to share with students. She is concerned that if she leaves students with the model answer they may copy it, but decides that imitation is part of apprenticeship; removing models prevents students from returning to them as they work. She is also confident that any copying will be obvious: she decides to leave students with the model work. She wonders whether showing students one model will be sufficient, however; students may not be able to tell the difference between a good piece of work and a mediocre one. She needs to help them compare.

Version 4

Anne decides to show models of differing levels of quality. Contrasting examples seems to help students understand the criteria for great writing, improving their self-assessment, their choice of strategies to improve and their writing (Lin-Siegler, Shaenfield and Elder, 2015). Comparison seems

to have helped students generate the differentiated knowledge structures that enabled them to understand deeply what specific good features to include and what specific poor features to avoid in the story writing. This resulted in recognition of poor aspects of writing, generation of strategies to correct them, and willingness to revise and make improvements. (p. 531)¹

Anne identifies a model of excellent work from the previous year, borrows an average model from two years ago from a colleague and writes a poor model which incorporates many common errors herself. Anne decides to share the models early in the unit and to ask students to refer to them in their planning and writing. Sharing models may be insufficient, however. Anne worries that students may not recognise what makes the work good and may fixate on punctuation or length: necessary qualities, but insufficient for success. "Simply providing students with contrasting cases does not automatically produce deep understanding and self-assessment," however (Lin-Siegler, Shaenfield and Elder, 2015, p. 533). Students need to consider what success looks like carefully:

We cannot assume that simply being shown excellent work is enough to develop excellence. Something more is needed: either the complex task needs to be broken down, or particular aspects of a quality piece of work need to be explicitly highlighted and emphasised by a teacher.

(Christodoulou, 2017, p. 42)

Version 5

Anne goes back to Berger's work, and notes how he and his students use examples:

We sit and we admire. We critique and discuss what makes the work powerful: what makes a piece of creative writing compelling and exciting; what makes a scientific or historical research project significant and stirring; what makes a novel mathematical solution so breath-taking.

(2003, p. 31)

Anne realises why 'student-friendly mark schemes' seemed helpful: students articulating the criteria for excellent work in their own words makes sense. Where she went wrong, however, was in copying the technique without understanding this: she gave students mark schemes, but students must begin with the models and, understanding them, articulate the standards they reach. Anne seeks tasks which will help students engage critically with the models and allow them to codify success in their own words. She identifies several powerful approaches:

5a) Comparing models

Students read examples of strong, average and weak paragraphs. This begins as a game of 'spot the difference', and then they highlight and describe strengths and weaknesses of each paragraph. Anne leads discussion of the strengths of a good paragraph; then she uses the weakest model as a completion problem, asking students to rewrite it using the strengths they have identified.

5b) Identifying criteria

Students read a strong and a weak experiment report. They compare them, section by section, and formulate what a strong report must include. This forms a checklist for them, but also leads them to return to the models as they write their own reports, rather than relying on the list of criteria alone.

5c) Comparing possible choices

Anne shows students problems, sentences or movements, and then offers a range of choices for the next word, number or movement. She asks students to choose what works next: which sentence will most elegantly conclude the argument, which word will complete the sentence grammatically, which line of working should come next. Anne gives students a hinge question (Problem 5) each time to check who has chosen what, and then asks students to explain the

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reasons for the choices they have made. Students get used to seeing each action and word as a choice and identifying the choices which work best.

5d) Examining improvements

Anne shows the process of improvement by sharing a weak paragraph and the same paragraph edited and improved. She invites students to identify the changes and explain the impact they have had. Then she asks students to apply the changes they have noticed to a new, weak paragraph, or to their own work.

5e) Live modelling

When Anne identifies an issue during a lesson and wants to remind students what success looks like, she sometimes models live. She revises and edits student work, or her own, on the board, asking students what her next move should be and why. Anne finds this a powerful way to give feedback to the whole class (Problem 6).

5f) Articulating success

After encountering the model, Anne asks students to record what they will remember about it. Sometimes, she asks them to codify this using a weak example: "What advice would you give to the person who wrote this?" Sometimes, she asks them to write goals for their own work. Anne returns to models across units; she asks students who are struggling or have made mistakes to return to strong models and identify what they have missed, or return to weak models and identify the traps into which they have fallen. Sometimes, Anne even has students draft answers first and then examine models; having begun the task, students can identify the choices made in the model better.



Experience - Michael Pershan

Helping students see what they can't yet see

Michael Pershan has been a math teacher in New York City since 2010, a few months after he graduated from university. It's the only job he's ever had, besides the little things over the summer when he was a teen: babysitter, camp counsellor, Pepsi vendor at a baseball stadium, tutor - all kind of relevant to teaching.

Though I teach math, math didn't feel easy for me as a student. It was never where I shined. An exception was geometry, with its heavy emphasis on proof. Proof felt natural for me in a way that algebra didn't.

When I began teaching, I realised that for many students the situation is reversed - it's proof that feels unnatural and cumbersome. Writing a proof involves combining statements in ways that seemed to mystify many students. This was especially true early in my career.

After a few years of hitting my head against the wall, I started to understand what made this such a difficult skill to teach. Proof is the closest that mathematics comes to writing, and writing itself is impossible without reading. How can a student who has never read an essay possibly write one? I concluded that my students needed to read more proofs.

It took me a few more years to understand how exactly to pull this off in class. My big frustration was that my students wouldn't devote enough attention to the proof examples I shared. I would distribute a completed proof and ask the class to read it with care. Very often, it seemed that they missed the whole point of the proof. They couldn't read it carefully yet - they didn't know how.

Now, things go better when I share proofs in class. One big difference is I have a much better understanding of all the subtle conceptual understandings that go into a proof, many of which were invisible to me at first. (In teaching, it can be trouble when a topic comes naturally to you.) There are many aspects of a proof that I need to help them uncover.

Besides a better understanding of the subtleties of the proof, I've learned to structure my activities in sturdier ways. I've learned to design these activities so that they have three parts:

- 1 The proof example
- 2 Comprehension questions about the example
- 3 Proof-writing practice, with the example as a model

I didn't come to this structure on my own, by the way. I came to it through reading about Cognitive Load Theory (where these are sometimes called "example-problem pairs") and especially from seeing it in some especially well-designed curricular materials. (In fact, I didn't really understand how to make my own example activities until I saw many models in these curricular materials. I needed examples, myself.)

So, for instance, I created the proof example seen in Figure 3.1 for my students this year.

Looking back, the example isn't perfect. It ended up being a bit visually crowded, and it might have been better to eliminate some of the letter abbreviations. In class, I actually covered up each stage of the proof to focus their attention on each part.

In any event, this activity shows a lot of what I've learned about teaching proof. I knew I wanted to make explicit the complicated two-stage structure of some congruence arguments, so I worked hard to create a pretty clear example for my students. I then called on students to answer a trio of analysis questions about the proof - there's a lot to notice, and students don't yet know how to notice the underlying structure of this kind of proof all on their own. Finally, I asked students to use what they'd noticed on a related pair of problems, so that students saw there was something that was generalisable to many different kinds of diagrams.

Even when my proof activities aren't structured so rigidly, I try to include variety and a chance to practice. Figure 3.2 shows a simpler activity, but I still call for students to do a bit of proof-completion in the second prompt:

Sometimes when I talk to other teachers about examples, they tell me they're worried that kids will just try to unthinkingly copy the model. I do know what they mean, but it's not what I see with my kids. I think that part of the reason is that I reserve example-analysis for when I worry that the math is going to be difficult, even overwhelming for many students. There is certainly a way to misuse these activities, and perhaps if I used these sorts of tasks on less complex material I would see unthinking imitation.

One of my jobs is to help students see things that they can't yet see - things like the logical structure of a good mathematical argument, or the way just a tiny bit of

Congruent Triangle Proofs

Name: _____

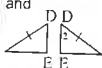
Example - Tina proved this correctly. Go Tina!

Proof

Prove that DB is perpendicular to AC.



$\triangle ADB \cong \triangle CDB$
by SSS,
therefore $\angle 1 \cong \angle 2$,
and



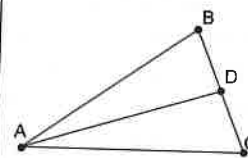
$\triangle DAE \cong \triangle DCE$
by SAS,

So $\angle AED \cong \angle CED$ and so each angle is 90° , and $\overline{DB} \perp \overline{AC}$. $\square$

Practice

$AB = AC$, and AD bisects angle BAC.

- Prove that D is the midpoint of BC.
- Show that AD is perpendicular to BC.



Analysis

- What two triangles did Tina first prove to be congruent? What info did she use to guarantee their congruence?
- What two triangles did Tina next prove to be congruent? What info did she use to guarantee their congruence?
- Why does proving that angle AED and AEC are congruent prove that the lines are perpendicular?

M is the midpoint of AC. Is it also the midpoint of BD?

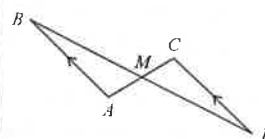
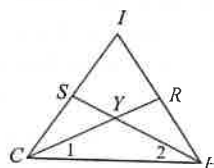


Figure 3.1 Proof example

Name: _____

$\overline{CS} \cong \overline{HR}$, $\angle 1 \cong \angle 2$
Is $\overline{CS} \cong \overline{HR}$?

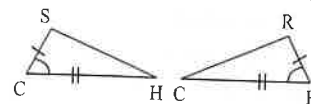


Timothy's Argument

No, because if $\angle ICR$ is wider there is a way to make $\overline{HS}$ longer than $\overline{CR}$ while keeping $\angle 1 \cong \angle 2$ and $\overline{CS} \cong \overline{HR}$.

Louise's Argument

Yes, because if you separate the overlapping triangles they are $\cong$ by SAS.



- Where is the mistake in the mistaken argument?
- For the mistaken argument to be true, what would the given information have to say?

Figure 3.2 Proof completion

information about a shape can guarantee a whole lot more. When things don't come naturally to my students, what I'm learning to do is to design an activity that opens up a little window into the mathematics so they can learn to see new things.

Conclusion

Anne has found ways to show students what success looks like. She tries to keep in mind that the criteria students articulate are simply descriptions of success; they can help students recall and articulate what they need to do, but they are abstractions from the models and cannot replace the models. She recalls the expertise reversal effect, too (Sweller et al., 2003): support which helps initially can hinder students once they have gained expertise. Early in the year, she helps students extensively in identifying the features of success; later, she expects students to identify these features with less support. Finally, she returns to the models in her feedback (Problem 6); now that students are clear what success looks like, Anne can highlight the gap between their work and the models, or have them identify that gap themselves. This deepens their sense of the features of success and their understanding of the quality of their own work. Having established for students what success looks like, Anne is keen to check what students have learned.



Checklist

- 1 Identify, obtain or create model work at different levels ☐
- 2 Identify key points students should be able to articulate, based on the models ☐
- 3 Design a task which will cause students to concentrate on the features of interest ☐
- 4 Prepare questions to further student thinking ☐
- 5 Consider asking students to improve weak models as completion problems ☐
- 6 Plan a way for students to record what they have learned ☐
- 7 Plan to return to the models later in the unit ☐

Double-check to avoid:

- Only showing excellent models ☐
- No opportunity to engage with the model ☐

A great read on this is . . .

Sadler, D. R. (1989). Formative assessment and the design of instructional systems. *Instruction Science*, 18, pp. 119-144.

Sadler explains how feedback and self-monitoring should work: the teacher sharing exemplars, leading students to experience and understand what leads to success and helping them to close the gap between the desired level of success and their own performances.

Note

- 1 This is also why I have offered both examples of successful applications of the principles and examples of near-misses throughout the book, in the hope of clarifying the principle.