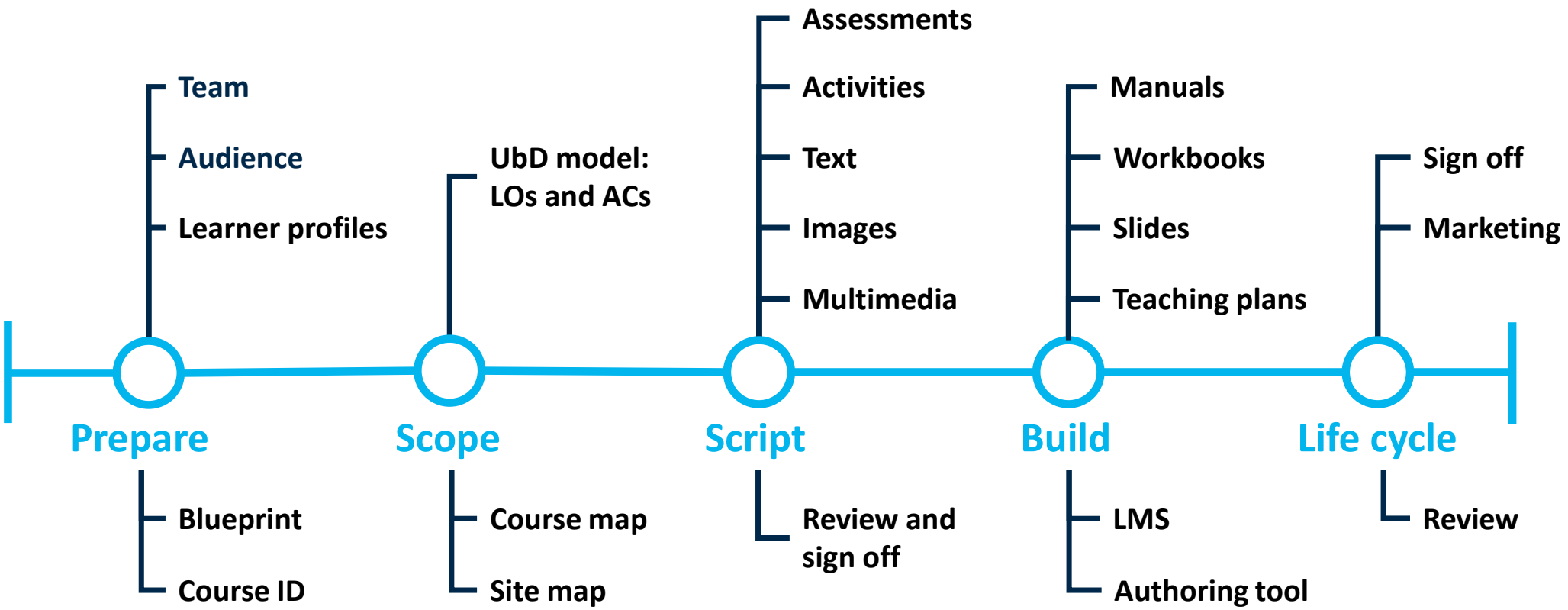
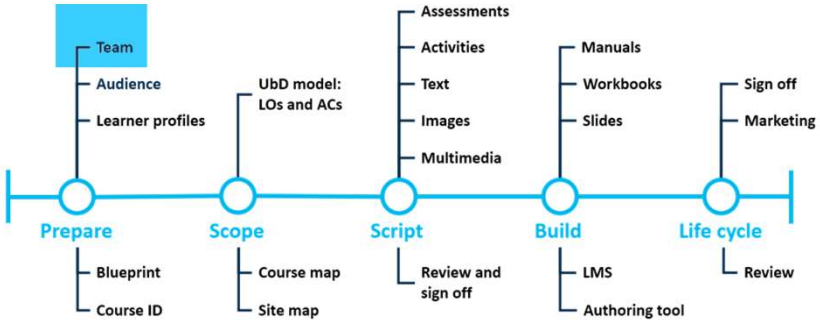
NPL's training development process

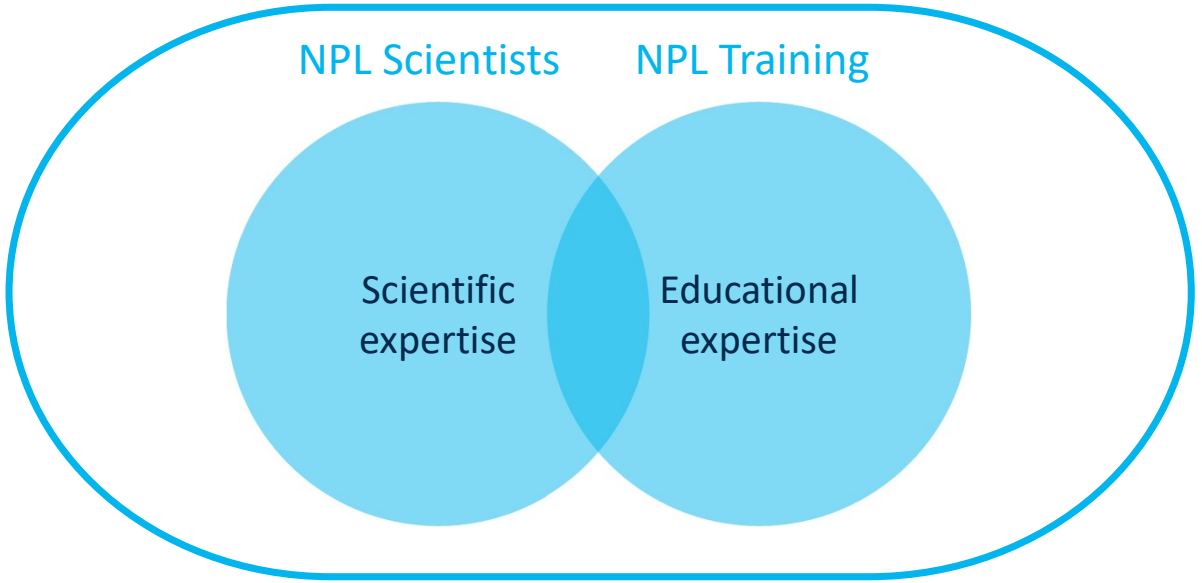


PREPARE:
Team

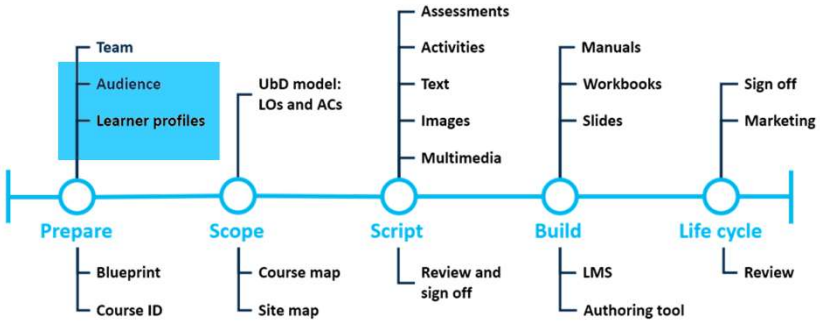


NPL have a dedicated Training team.
We are scientifically literate, but not professional scientists.

The project team consists of members of NPL Training plus technical experts from the science teams.



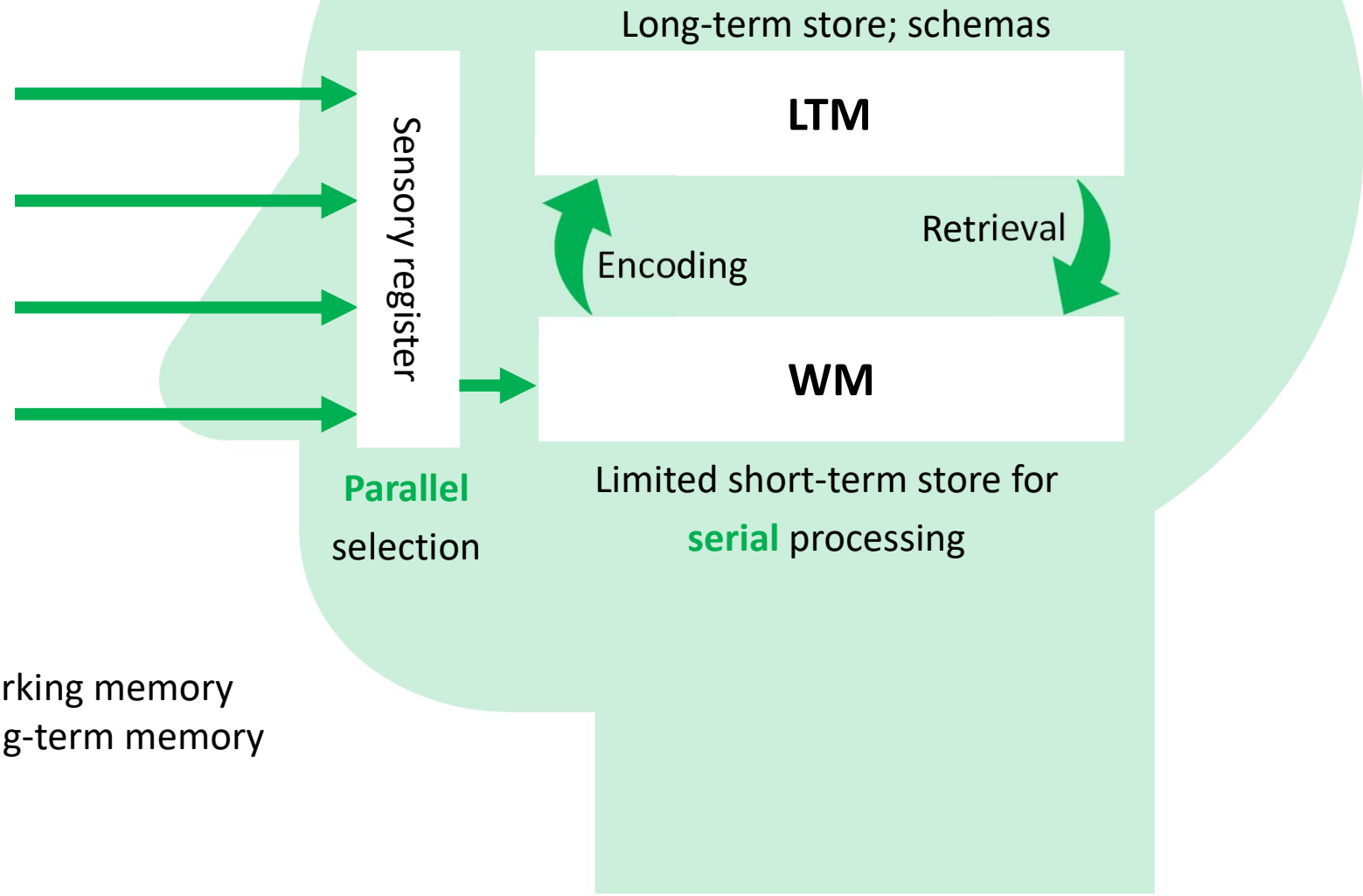
PREPARE:
Audience and learner profiles



Understanding the audience is essential.

A brief introduction to some learning theory might help with Task 2.3.

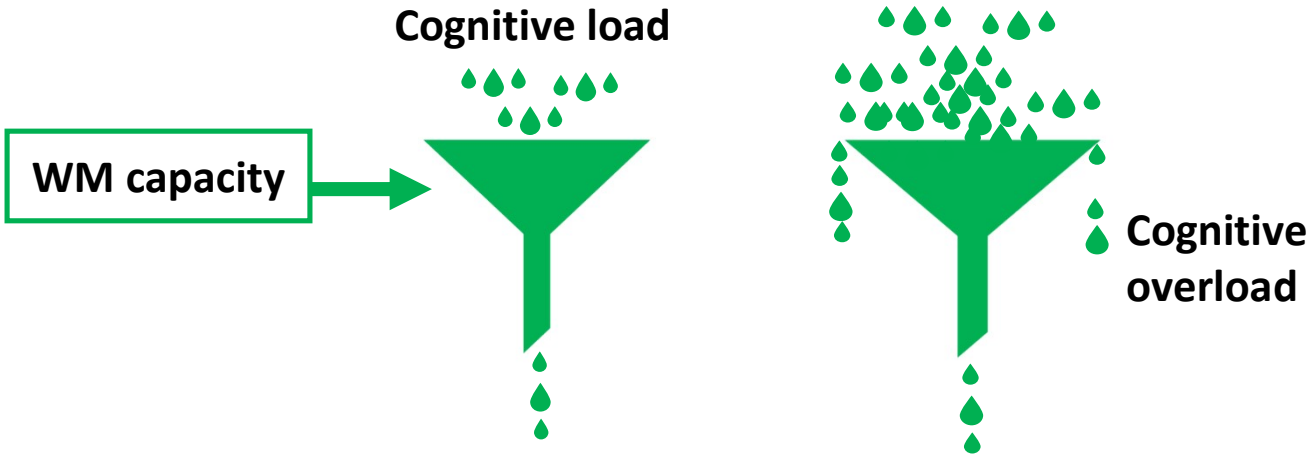
A model for information processing

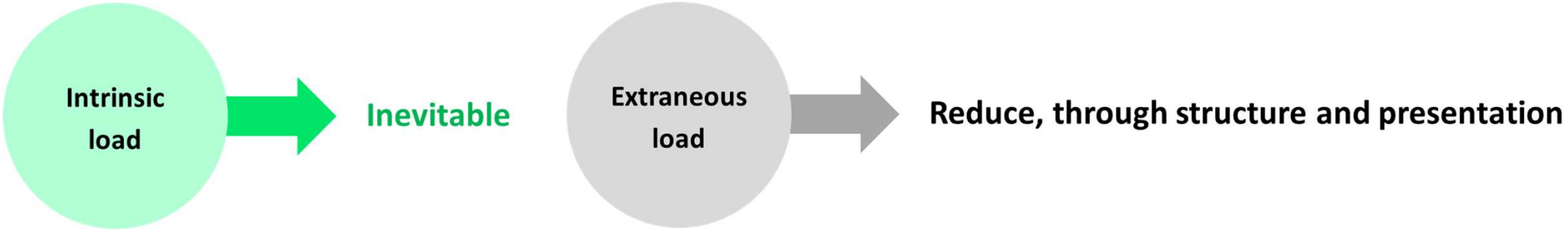


WM = Working memory
LTM = Long-term memory

Working memory capacity and cognitive load theory (CLT)

Any task has a ‘cognitive load’, which may or may not be within WM capacity.

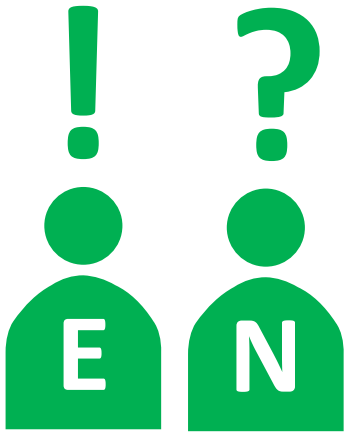




Experts and novices

I categorise problems by deep structure.

But my expertise is narrow. Elsewhere I too am a novice.



I categorise problems by surface features.

The more novice the learner, the more they need signposts to help them bolt new learning onto their existing understanding.

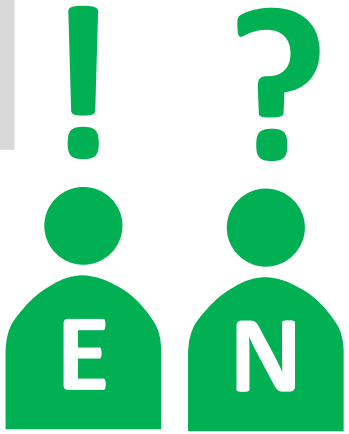
Just because your audience is ‘clever’ doesn’t mean they are experts.

Automaticity

Automaticity is the execution of a skill without devoting attention to it.
When we master a skill and it becomes automatic, it bypasses the WM.

I can have a conversation while driving.

Stop talking! I'm driving!



I've forgotten what it's like to find $C = 2\pi r$ non-obvious.

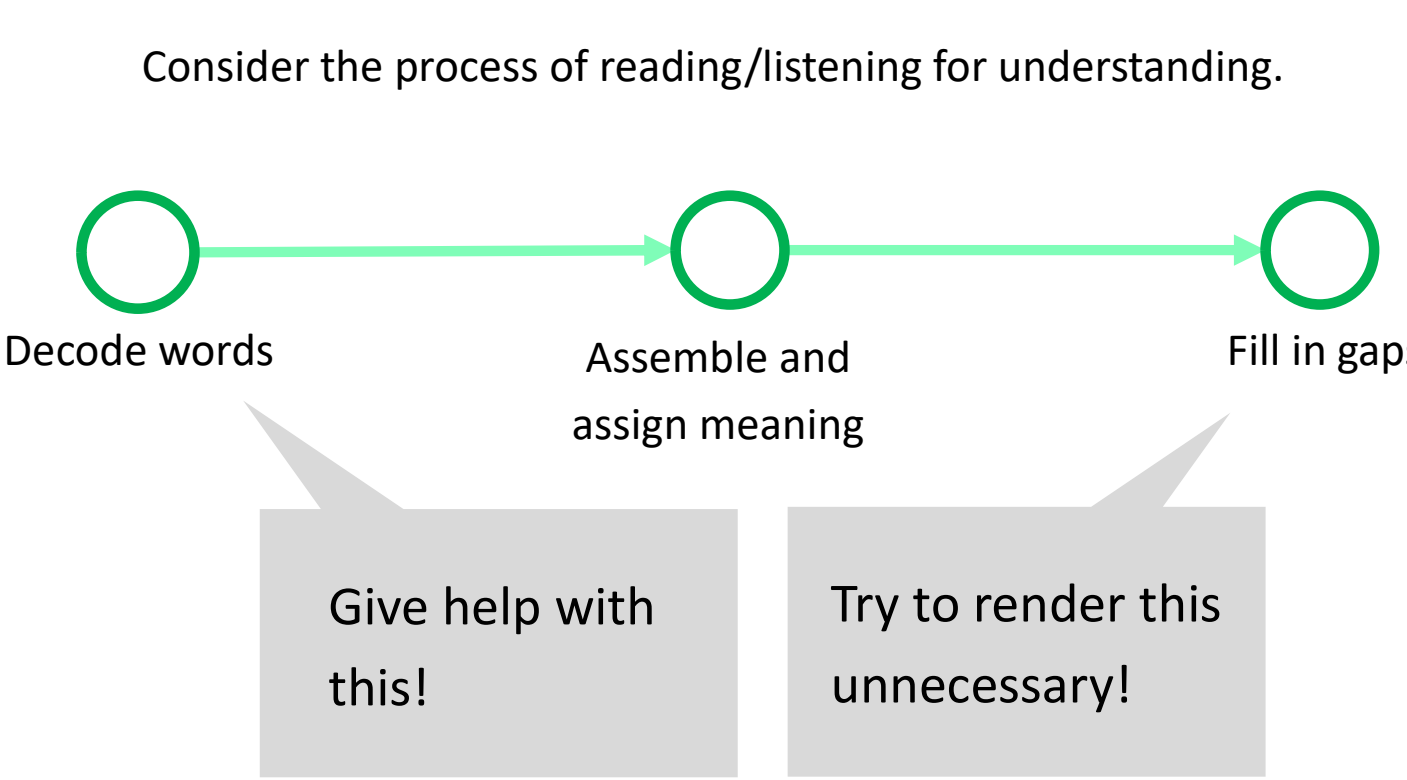
$C = 2\pi r$

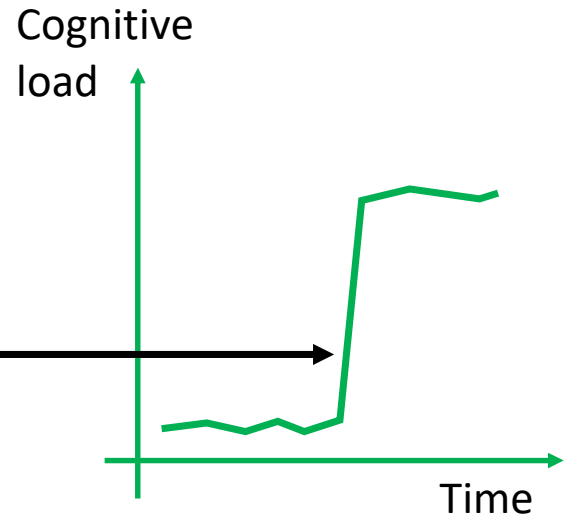
How many 'slots' of working memory?

- 5 to 7 for a novice.
- 1 for an expert

Conceptual cliffs

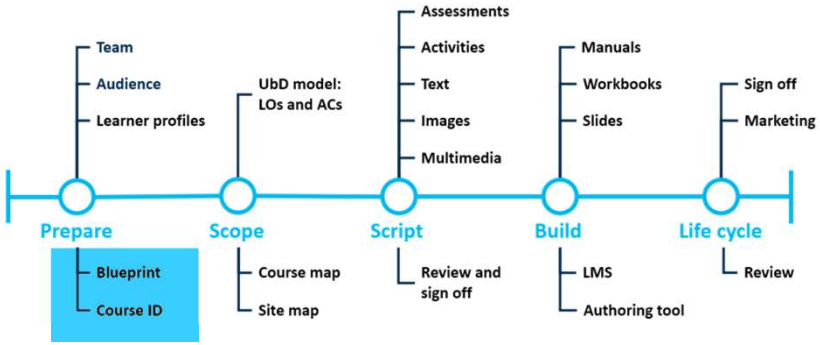
Consider the process of reading/listening for understanding.





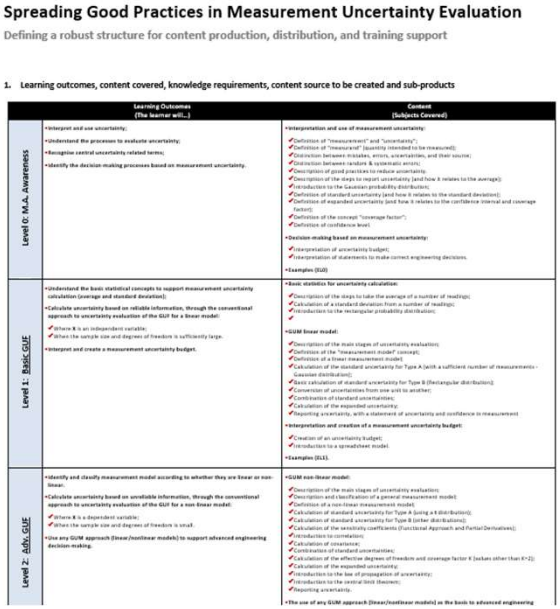
PREPARE:

Blueprint and course identification



So, with the audience at the focus of our attention*, we create a Blueprint.

***… it's surprisingly easy to understand and believe all the learning theory we have seen, and still not take it into account…**



Spreading Good Practices in Measurement Uncertainty Evaluation

Defining a robust structure for content production, distribution, and training support

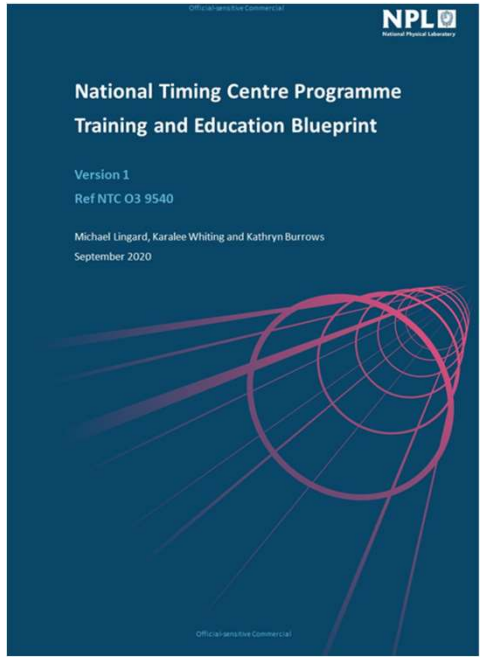
1. Learning outcomes, content covered, knowledge requirements, content source to be created and sub-products

	Learning Outcomes (The learner will…)	Content (Subjects Covered)
Level 0: M.A. Awareness	•Interpret and use uncertainty; •Understand the processes to evaluate uncertainty; •Recognise central uncertainty related terms; •Identify the decision-making processes based on measurement uncertainty.	•Interpretation and use of measurement uncertainty: ✓Definition of "measurement" and "uncertainty"; ✓Definition of "measurand" (quantity intended to be measured); ✓Distinction between mistakes, errors, uncertainties, and their source; ✓Distinction between random & systematic errors; ✓Description of good practices to reduce uncertainty. ✓Description of the steps to report uncertainty (and how it relates to the average); ✓Introduction to the Gaussian probability distribution; ✓Definition of standard uncertainty (and how it relates to the standard deviation); ✓Definition of expanded uncertainty (and how it relates to the confidence interval and coverage factor); ✓Definition of the concept "coverage factor"; ✓Definition of confidence level. •Decision-making based on measurement uncertainty: ✓Interpretation of uncertainty budget; ✓Interpretation of statements to make correct engineering decisions. •Examples (ELO)
Level 1: Basic GUF	•Understand the basic statistical concepts to support measurement uncertainty calculation (average and standard deviation); •Calculate uncertainty based on reliable information, through the conventional approach to uncertainty evaluation of the GUF for a linear model: ✓Where X is an independent variable; ✓When the sample size and degrees of freedom is sufficiently large. •Interpret and create a measurement uncertainty budget.	•Basic statistics for uncertainty calculation: ✓Description of the steps to take the average of a number of readings; ✓Calculation of a standard deviation from a number of readings; ✓Introduction to the rectangular probability distribution; ✓ •GUM linear model: ✓Description of the main stages of uncertainty evaluation; ✓Definition of the "measurement model" concept; ✓Definition of a linear measurement model; ✓Calculation of the standard uncertainty for Type A (with a sufficient number of measurements - Gaussian distribution); ✓Basic calculation of standard uncertainty for Type B (Rectangular distribution); ✓Conversion of uncertainties from one unit to another; ✓Combination of standard uncertainties; ✓Calculation of the expanded uncertainty; ✓Reporting uncertainty, with a statement of uncertainty and confidence in measurement •Interpretation and creation of a measurement uncertainty budget: ✓Creation of an uncertainty budget; ✓Introduction to a spreadsheet model. •Examples (ELL).
Level 2: Adv. GUF	•Identify and classify measurement model according to whether they are linear or non-linear; •Calculate uncertainty based on unreliable information, through the conventional approach to uncertainty evaluation of the GUF for a non-linear model: ✓Where X is a dependent variable; ✓When the sample size and degrees of freedom is small. •Use any GUM approach (linear/nonlinear models) to support advanced engineering decision-making.	•GUM non-linear model: ✓Description of the main stages of uncertainty evaluation; ✓Description and classification of a general measurement model; ✓Definition of a non-linear measurement model; ✓Calculation of standard uncertainty for Type A (using a t distribution); ✓Calculation of standard uncertainty for Type B (other distributions); ✓Calculation of the sensitivity coefficients (Functional Approach and Partial Derivatives); ✓Introduction to correlation; ✓Calculation of covariances; ✓Combination of standard uncertainties; ✓Calculation of the effective degrees of freedom and coverage factor k (values other than K=2); ✓Calculation of the expanded uncertainty; ✓Introduction to the law of propagation of uncertainty; ✓Introduction to the central limit theorem; ✓Reporting uncertainty; •The use of any GUM approach (linear/nonlinear models) as the basis to advanced engineering

… an outline pathway through a content area…

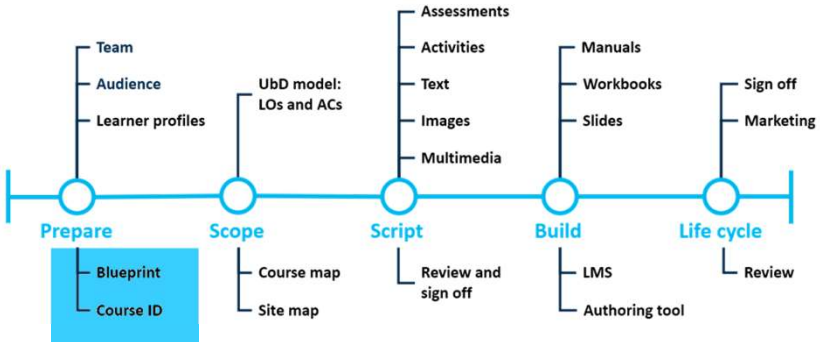
… varies in complexity and scale depending on the nature of the project.

Then our New Product Introduction system identifies and prioritises courses to develop.



PREPARE:

NPL's MU pathway



Introduction to Measurement Uncertainty

Understanding Uncertainty Budgets

Understanding and Evaluating Measurement Uncertainty

Bayesian approaches to Measurement Uncertainty Evaluation

Increasing technical demand

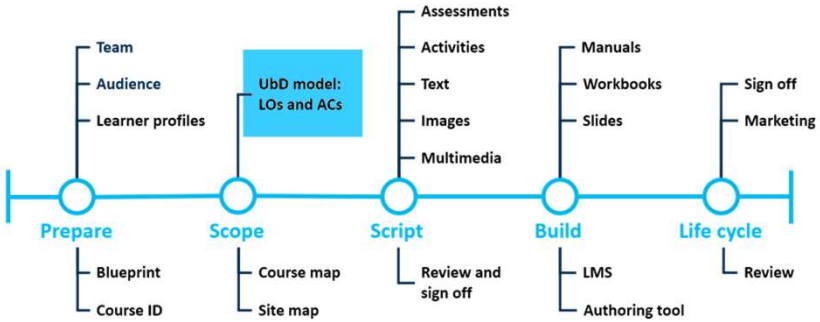
Aligns to NPL GPG11

Aligns to GUM, M3003

Aligns to GUM plus supplements

Aligns to GUM plus supplements

SCOPE:
The UbD model



Once the course is identified, one model for creating content is called Understanding by Design. That requires the following activities, in this order.

Learning outcomes: what do we want the learners to get out of it?
(note: this is much easier if we know who they are and why they are here)

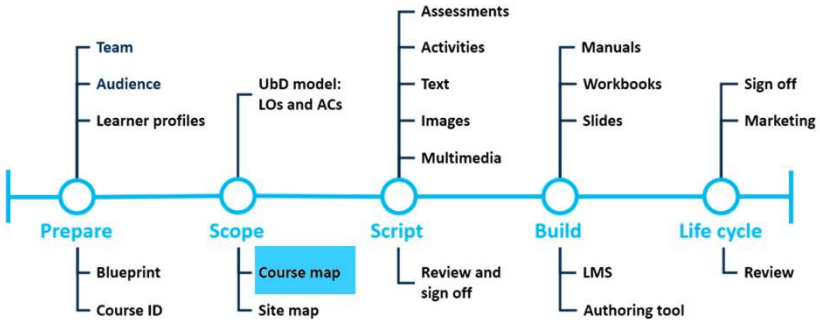
Assessment criteria: how will we (or they) know they have done that learning?

Activities and assessments: what will they do to generate that learning? And how will we tell?

Resources: what do we provide to help them do their learning?

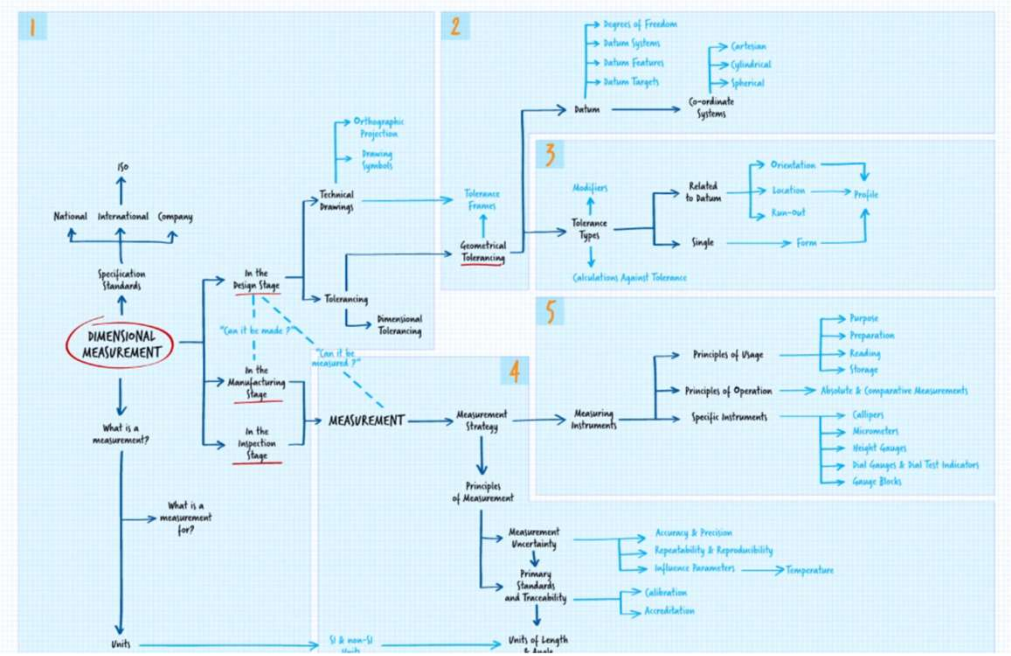
It hardly ever works out like that.

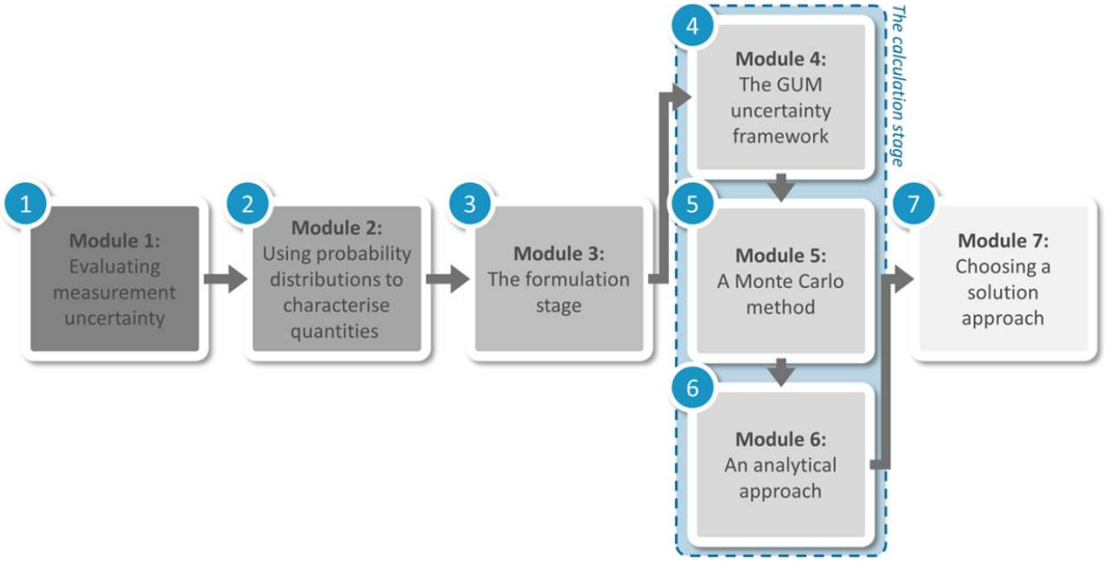
SCOPE:
Course maps



The more novice the learner, the more they need signposts to help them orientate themselves within their learning, and bolt new understanding onto their existing knowledge.

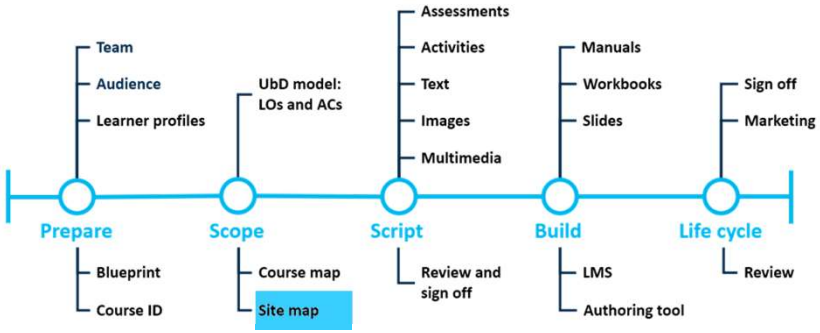
Our course maps are to help the learner, but also to help the course creator.





SCOPE:

Site maps for online courses



In contrast, these are for the development team, and provide a discussion forum as well as a record of decisions

Module 2: 'Introducing time scales'

Module Description on Course Home Page	Description
	In Module 1 we saw that clocks measure time intervals, but not how they tell 'the time'. This module will explore the concept of time scales as a time reference. We will discuss how today's standard time scale, known as Coordinated Universal Time (UTC), developed over the years. We will also explore how UTC relates to historical methods of telling time using astronomical methods, and the traceability chain for time.

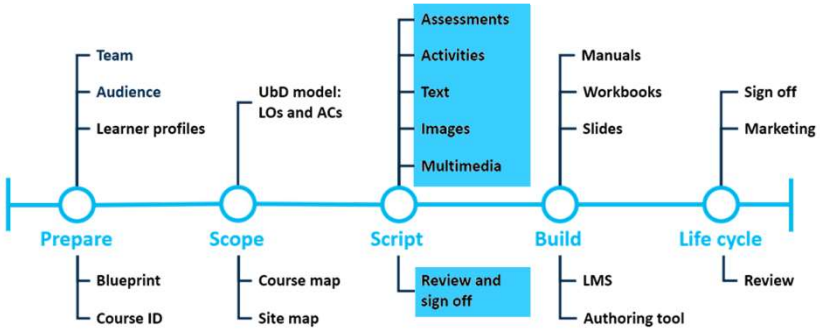
Lesson	Sub-lesson (not always necessary)	Pages within sub-lesson (if blank then the lesson or sub-lesson page is the only one needed)	To cover	Page Number
Lesson 1: What is a time scale?				
		Measuring time intervals	Clocks only measure time intervals; examples	1
		Time references	Time intervals vs time references vs frequency references	2
Lesson 2: Solar time and its limitations				
		Apparent solar time	What is a day? The meridian and the Sun's apparent path in the sky	1
		Mean solar time	Mean solar time; local time	2
		Standardising time - GMT	Local time, Railway time, GMT, time zones	3
		Universal time	~~UT0, UT1, UT2~~As derived originally from GMT Different versions, concentrating on UT1 and how it is a measure of Earth's angular orientation in space [Grey box on ET if required – let's omit if we can]	4
			Said in M1 that atomic clocks are more stable oscillator than the Earth. That's another way of saying that the length of a day (as defined by Earth's rotation) is not constant. That is, UT does not run at a perfectly stable rate	

[redacted]
This could potentially be linked into the SI second, the unit of time comes from a frequency reference. It allows us to measure time intervals but to all consistency agree the 'time' we need to set our origin to be the same time reference -> time scales.

[redacted]
That's a good nuance we can certainly include!

SCRIPT:

Assessments, text, images, multimedia, review and sign off



In the same way that we focus on the audience when planning the course/programme…

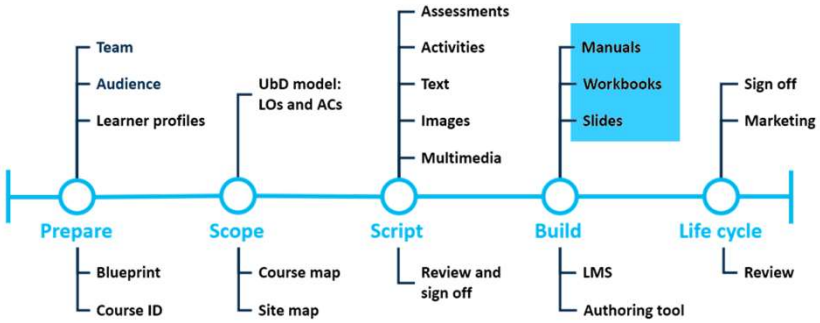
…we write content focusing on the learner experience.

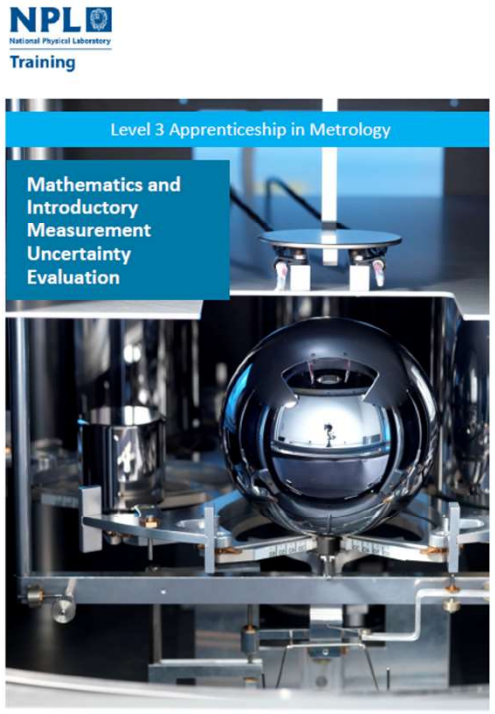
For online learning, we create a Word doc called the script that describes every element of what will appear in the finished version.

The script is always reviewed and signed off by the allocated technical expert before build commences.

BUILD:

Manuals, workbooks, slides, teaching plan





NPL
National Physical Laboratory
Training

Level 3 Apprenticeship in Metrology

Mathematics and Introductory Measurement Uncertainty Evaluation

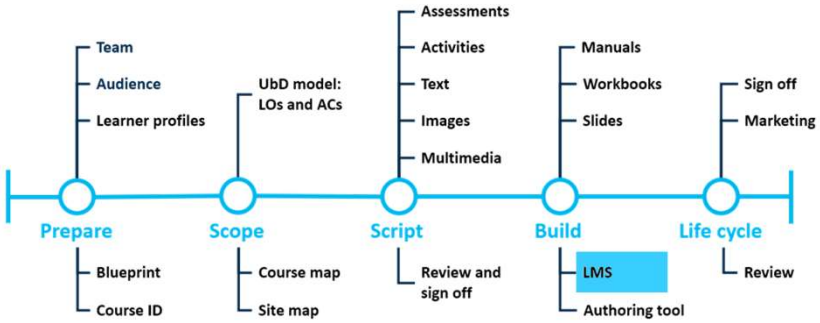
5 days

training@npl.co.uk

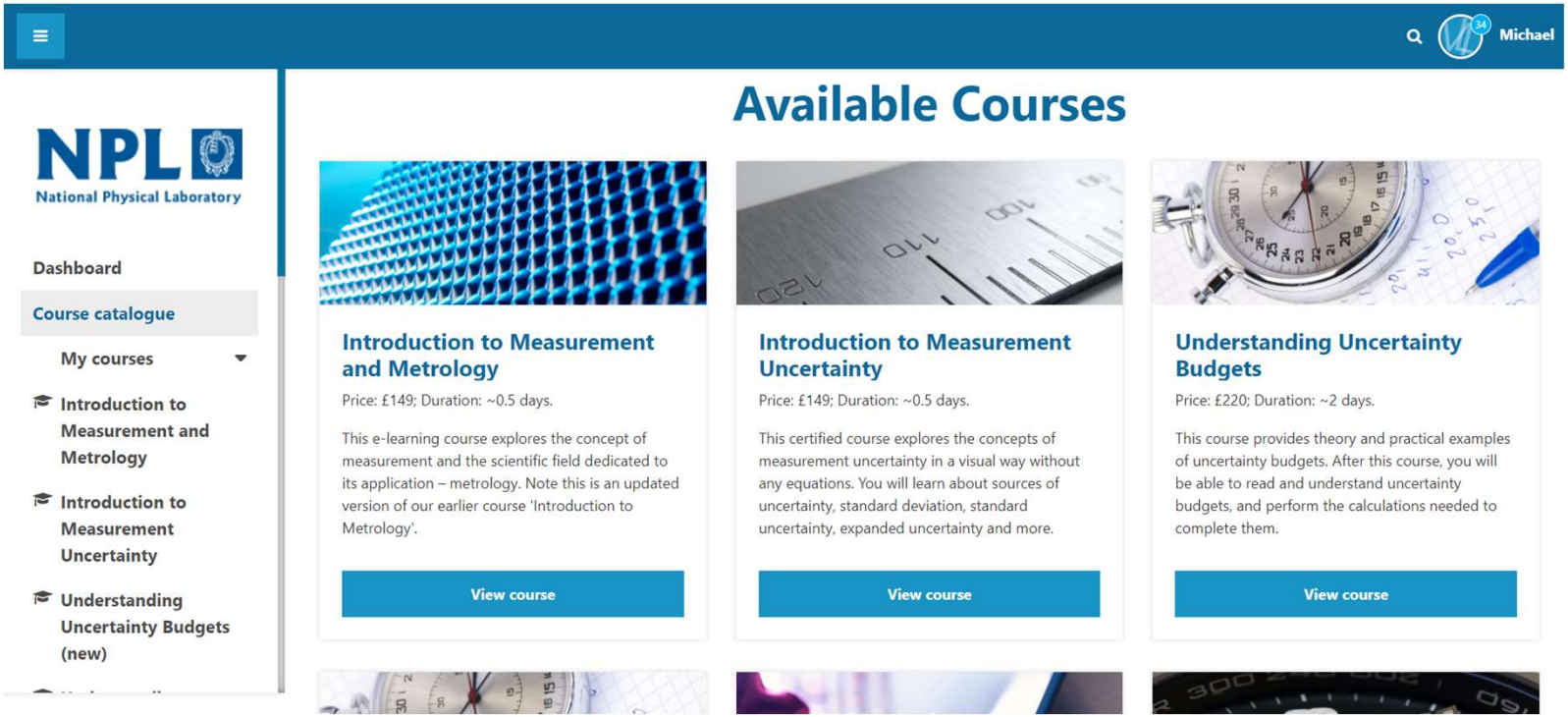
Teaching / Content Sequence

	TEACHING SEQUENCE (key concepts covering the above learning objectives, and activities to support them)	Include here any details of the 'narrative thread'	Resource requirements	WORK SKILLS MAPPING
Day 1 a.m.	**INTRODUCTION:** • Recap of taught component of apprenticeship so far • Block introduction - topics covered and schedule **DISCUSSION:** The importance of mathematics in science and engineering (and metrology): • Encourage students to draw on examples from both their workplace and previous study (P4) • Trainer to help students to realise the far-reaching applications of mathematics and contextualise the topics covered in this block	Mathematics plays a vital role in science, engineering and metrology.		PI, T
	Chapter 1: Working with numbers **TEACH:** Use slides to recap: • Fractions • Decimals • Percentages • Rounding • Exponents • Powers of 10 **FORMATIVE ASSESSMENT:** Using the text book: • Learners to complete self-assessment questions on fractions, decimals, percentages rounding, exponents and powers of 10 (trainer to decide on which questions are best suited to the group) • Trainer to help individuals, and confirm that all individuals understand these topics	Before starting delivery the trainer to decide whether all sides are required, or whether to hide selected slides in order minimise time spent of specific sections. Learners should already be familiar with these topics – this section acts as a recap in order to cement understanding and refresh knowledge. Answers to these questions can be found at the back of the textbook.		SM, PI
	TECAH: Use slides to teach: • Logarithms **FORMATIVE ASSESSMENT:** Using the text book: • Learners to complete self-assessment questions on logarithms • Trainer to help individuals, and confirm that all individuals understand these topics Explain that, in the following practical: • You will be asked to use a pendulum to determine a value for the acceleration due to gravity • To do so, you will need to apply some of the properties of logarithms that we've learnt in this session	Some learners may not be familiar with logarithms. It is therefore suggested that this section is covered thoroughly, with use of worked examples, where possible.		SM, PI

BUILD:
Learning Management System

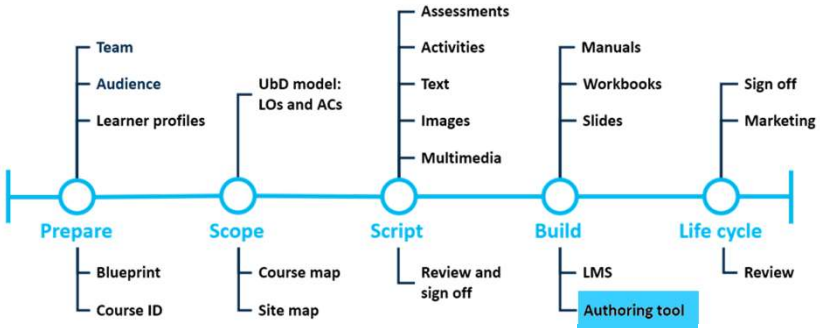


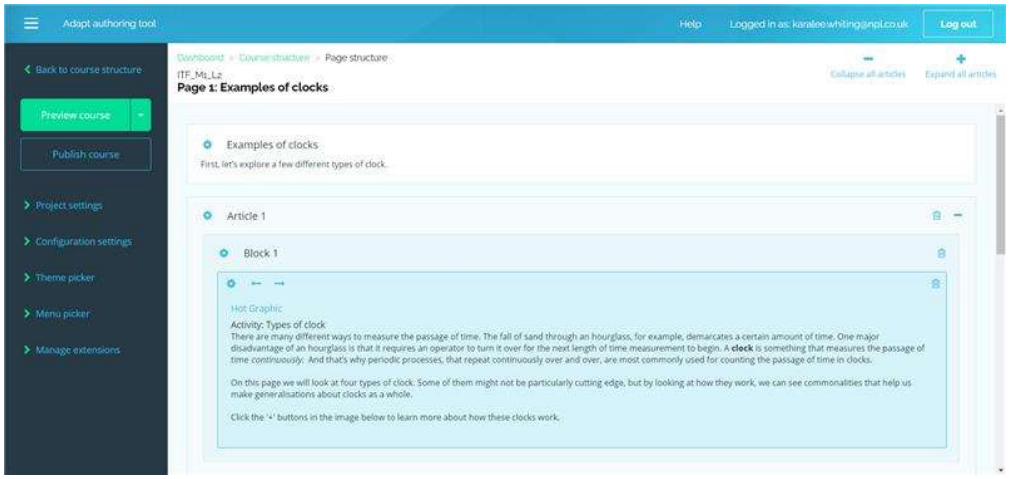
‘Configured, not customised.’

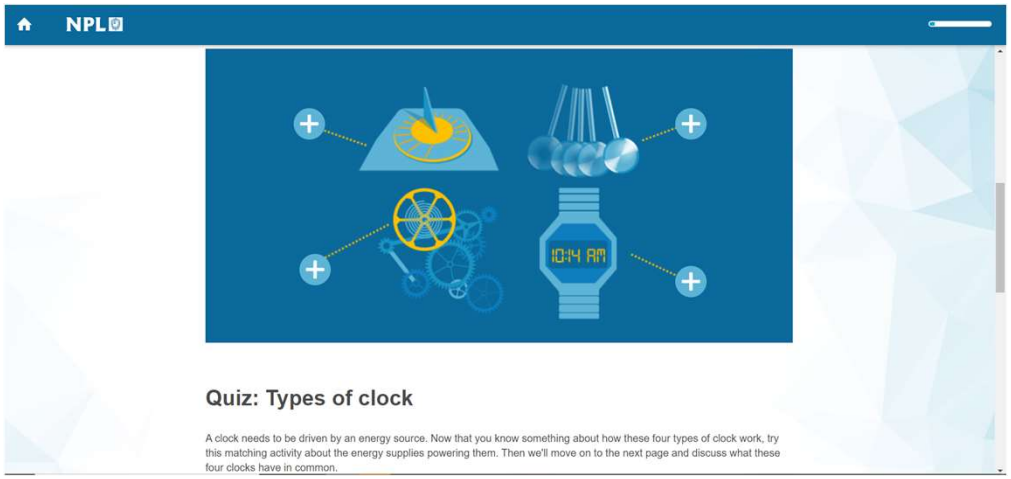


BUILD:
Authoring tool

Mathematical typesetting and accessibility were big constraints on our procurement of an authoring tool.







LIFE CYCLE:

Sign off, marketing, review