Supporting the student's learning journey through the transition of mathematics and statistics from level 2 to level 3

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Executive Summary

Mathematics and Statistics are linear subjects where success at higher levels depends on firm foundations, it is likened to a carpenter who is only capable of making a beautiful piece of furniture once they understand how a hammer and nail work. It is also the case that students succeed by regularly practicing mathematics, as it is not a spectator sport!

This eSTEeM funded project has allowed us to produce a suite of resources which allows students to self-identify the areas where they need to revise for transition between level 2 and 3 modules in maths and stats. Giving them a supported learning environment, where they can self-study and ask questions on a moderated "Pre-module help" forum.

Keywords: Revision, Student success, Preparation, Transition.

Aims and Scope of Project

The transition from level 2 to level 3 involves periods where students have no mathematical study and in some cases the foundations have been studied several years previously and are now no longer at a student's fingertips. There is a need for students to continue to practice techniques in a supported environment during the gap between modules and have appropriate advice on areas where they need to refresh previously established knowledge in order to have the best chance of succeeding in their chosen level 3 modules.

The School already provides a revise and refresh website for MST124: Essential mathematics (MST124) which focuses on topics required for successful study of MST124, a key level 1 module. A similar website was also developed for MST224:Mathematical methods (MST224) in the eSTEeM project Supporting MST224 students with bridging material during their transition from level one mathematics.

The first stage of the project was to scope out the areas where students struggle because of a lack of revision of earlier material. This was done via a questionnaire to ALs tutoring each level 3 mathematics and statistics module.

The final aim of this project was to build a website, based on the information gathered from ALs in the survey, where students can self-identify areas in need of revision from their level 2 modules in order to successfully study level 3 maths and stats, in a supported learning environment.

Activities: Survey of level 3 Maths and Stats ALs

A survey of the 83 Associate Lecturers (ALs) on Level 3 mathematics and statistics modules was run over November to December 2017. The survey aimed to identify potential topics and types of resources that may be useful for a 'revise and refresh' website for these students.

Of the 42 respondents 95% thought a revise and refresh website for Level 3 mathematics and statistics modules would benefit students. There were 26 Associate Lecturers that were interested in helping develop the resources, and these ALs between them covered all the Level 3 mathematics

and statistics modules, though some modules were better represented than others. Most of these ALs also had some knowledge of Level 1 and/or Level 2 modules. The types of resources and topics to be covered were generally supported and several additional ideas were put forward. The topics mentioned most often were calculus and algebra for all Level 3 mathematics and statistics modules.

One issue that came to light was that some ALs are unaware of the recent efforts to improve the Mathematics and Statistics website (https://learn2.open.ac.uk/course/view.php?id=206217), and how students find it from StudentHome or their module websites.

Sample and response rate

The survey was created and distributed by email using the Bristol Online Survey Tool to all 83 ALs with live contracts for Level 3 mathematics or statistics modules in the 2017J presentation, including those on leave of absence. There were 42 complete responses, giving a response rate of 50.6%. The responses from those 42 respondents have been evaluated.

Results

Q1: Do you think development of a 'revise and refresh' website for Level 3 mathematics and statistics modules would benefit students?

Most respondents thought a revise and refresh website would benefit students (Figure 1). The comments from the two respondents that were unsure were "I am not very sure what is being proposed." and "Most students will have completed Level 1 and 2 prerequisites. Some modules start with revision/basics anyway."
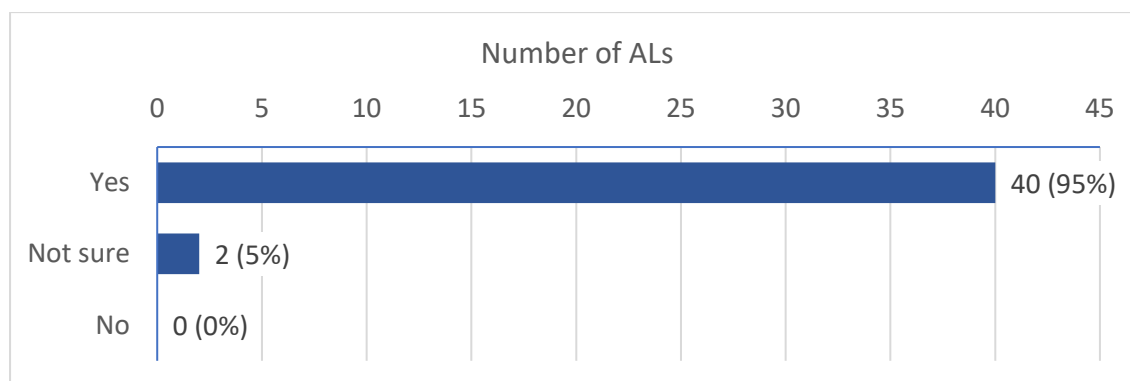
Figure 1: Do you think a Level 3 revise and refresh website benefit students?

Q3, Q4 and Q15: Would you be interested in helping develop 'revise and refresh' resources for Level 3 mathematics and statistics students? Which Level 1, Level 2 and Level 3 Modules do you have knowledge of?

The 26 ALs that said they were interested in helping develop the resources (Figure 2) covered all the current Level 3 modules between them (Figure 3). However, there were more ALs from some modules than others. M337 Complex Analysis was very well represented, with fewer ALs from the statistics modules (M343 Applications of Probability, M346 Linear Statistical Modelling and M347 Mathematical Statistics) and M373 (Optimization). Most of these ALs have knowledge of between 1 and 3 of the modules (Figure 4). Most of these ALs also have knowledge of some of the Level 1 and Level 2 mathematics and/or statistics modules, though 4 of the ALs do not have knowledge of these

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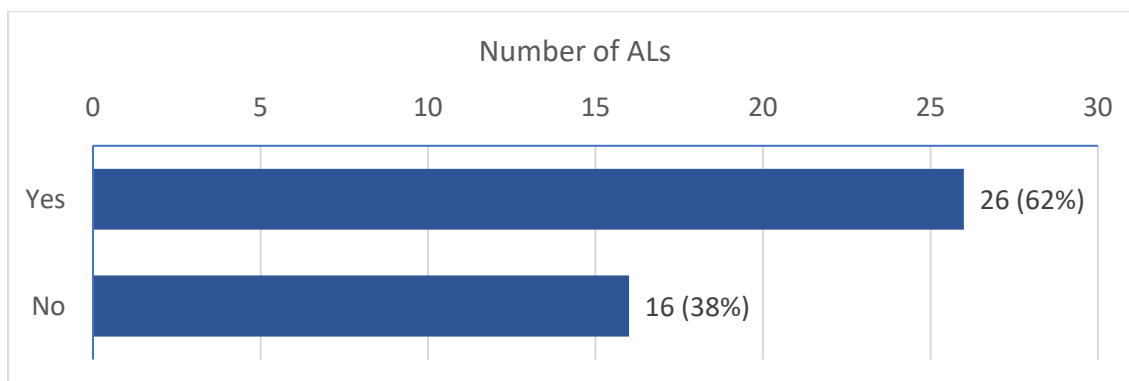earlier modules (Figure 5).

Figure 2: Would you be interested in helping develop the resources?
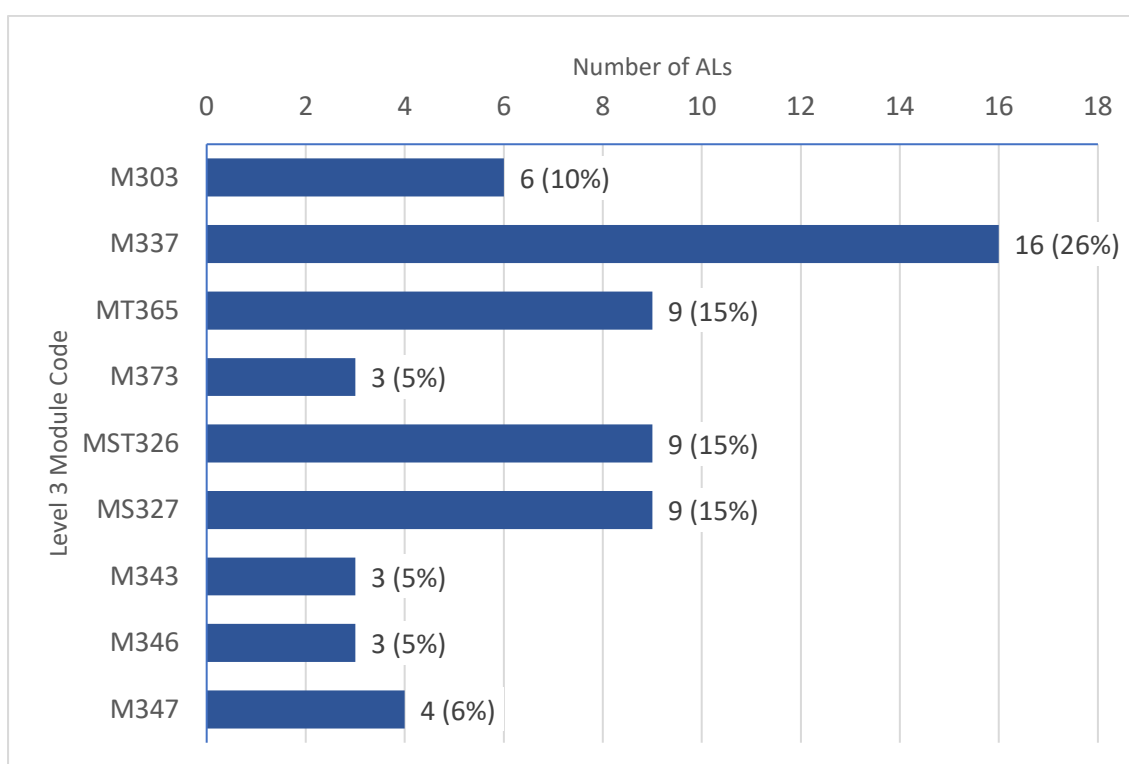
Figure 3: Knowledge of Level 3 modules for ALs interested in helping develop the resources.

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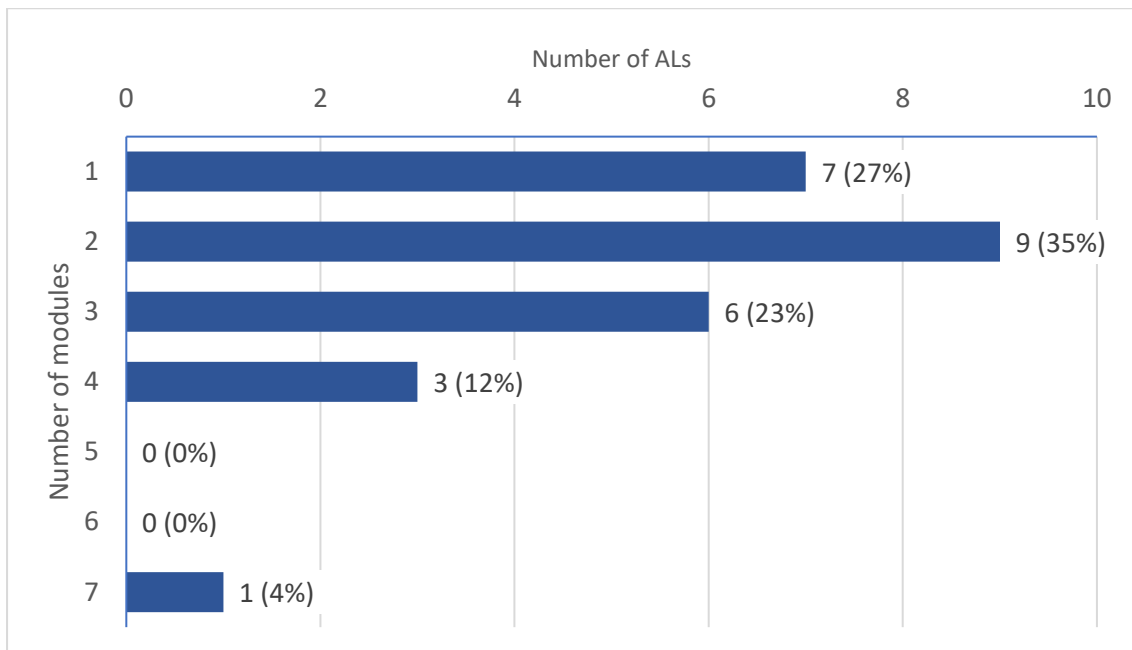
Figure 4: Number of Level 3 modules that ALs interested in helping develop the resources have knowledge of.
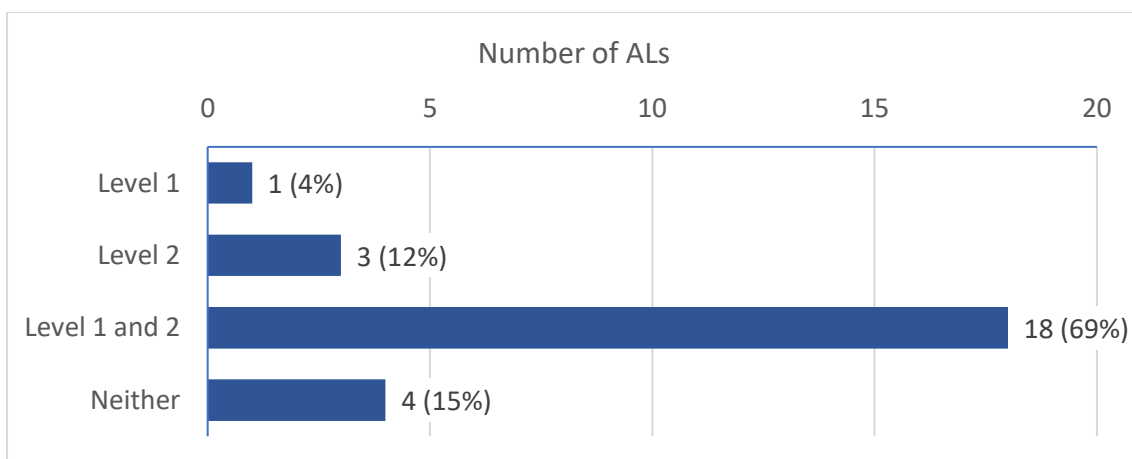

Figure 5: Involvement with Level 1 and/or Level 2 mathematics and statistics modules for ALs interested in helping develop the resources.

Q16: What types of resources do you think may be useful for students preparing to study Level 3 mathematics and statistics modules?

Respondents were given a list of some broad types of resources that might be used on a revise and refresh website and asked to say whether each suggestion was Very Useful, Useful, Neutral, Not Useful or Not at all useful (Table 1). Overall it was felt that all the types of resources suggested could be useful or very useful, but that having worked examples would be most useful (Figure 6). It was felt that moderated online forums could be useful, but were perhaps less so than other types of resources.

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Table 1: Number of AL responses for each type of proposed resource.

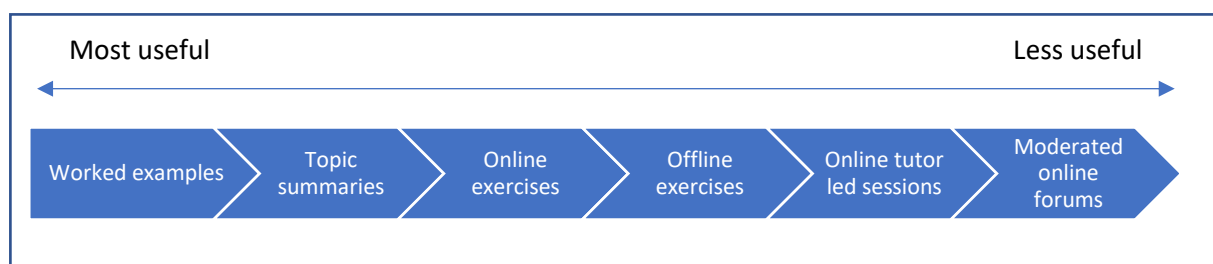| Resource type	Very useful	Useful	Neutral	Not useful	Not at all useful	Not completed	Total
Topic summaries	18	17	5	1	1		42
Worked examples	26	12	4				42
Online exercises	18	15	7	1		1	42
Offline exercises	17	12	11	1		1	42
Moderated online forums	10	12	14	5	1		42
Online tutor led sessions	13	11	15	3			42

Figure 6: Order of preference for types of resources that could be useful.

Q17. Please describe any other types of resources you think may be useful for students preparing to study Level 3 mathematics and statistics modules.

Thirty respondents gave suggestions for other types of resources (Appendix 1). Screencasts (or similar) were mentioned most often. Practice quizzes, applets and references/links to additional (non-OU) material were also mentioned.

Some of the comments were about what resources should be available and how they should be organised e.g. to allow a student to work out which resources for a particular module and as well which resources are useful across modules. Access to Level 1 and Level 2 materials and computer software also came up.

Other suggestions were more about getting a balance between practicing techniques, understanding concepts and developing mathematical reasoning.

Some of the answers suggest that not all ALs are aware of the Mathematics and Statistics website, as course choice, careers and student forums also got a mention.

Q18. Please describe anything you feel the University currently does that detracts from students being able to prepare for Level 3 mathematics and statistics modules.

There were 22 responses to this question (Appendix 2). One common theme was students don't always seem adequately prepared for Level 3 study, either because they have not studied earlier modules, that study was some time ago, or they underestimate the jump from Level 2 to Level 3. The idea that students are being "spoonfed" at Level 2 was also raised a few times, with the feeling

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there is more emphasis on applying techniques than developing broader mathematical understanding/reasoning. It was also mentioned that the taster material for Level 3 was either difficult to find or gives a false impression of the module as it tends to be the earlier units which often include revision of Level 2 material.

Q19 and Q20: Respondents were asked to comment on some suggested topics for Level 3 pure maths students and to suggest other topics that might be important. The suggested topics were:

- Algebraic manipulation
- Calculus
- Complex numbers
- Set notation and sketching sets in the plane
- Continuity
- Basic concepts of mathematical proof
- Group theory including subgroups, normal subgroups, quotient groups, conjugacy
- Sequences and series

These questions were completed by 29 respondents. Some other respondents commented that pure maths was not their area of expertise.

Calculus and algebraic manipulations were mentioned most often, alongside mathematical proofs (and logical reasoning), complex numbers, sets, continuity and sequences and series. Group theory was not specifically mentioned, but some respondents just agreed all the topics could be useful. Complex numbers were possibly mentioned more frequently than might have been expected and could reflect the high proportion of respondents from the M337 Complex Analysis module.

Most other additional topics were suggested by one or two respondents. These topics included:

• Referencing in maths (e.g. stating which theorems have been used in proofs) • Practice (of mathematical skills/techniques) • Inequalities • Calculus for complex numbers • Limits and linear dependence • Matrices and vectors • Concepts of functions, equivalence relations. • Analysis topics	• Checking your work • Matrices • Set theory, generalisation, equivalence classes • Logs and exponentials • Basic number theory, modular arithmetic • Modelling • Presentation of mathematics • Curve sketching

Q21 and Q22: Respondents were asked to comment on some suggested topics for Level 3 applied maths students and to suggest other topics that might be important. The suggested topics were:

- Algebra – including factorising, logs and exponentials
- Calculus – differential equations (including second order differential equations), partial differentiation, Taylor polynomials/series
- Vector algebra and calculus

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- Integration of scalar and vector fields
- Complex numbers
- Fourier series
- Matrices - determinants, eigenvalues/vectors, gaussian elimination

These questions were completed by 27 respondents. Some other respondents commented that applied maths was not their area of expertise. All the topics were thought suitable, with a particular emphasis on calculus and algebra. The most common suggestion for additional topics or material was about using Maxima and providing a range of examples that put theory into the real world context. Most other suggestions appeared only once or twice. Suggestions include:

- Presenting maths, typesetting, good mathematical communication
- Interpreting solutions in real world context
- Examples showing how techniques are used in different fields (economics given as example)
- Practice (of mathematical skills/techniques)
- Project work
- Modelling
- Numerical methods
- Maxima
- Partial fractions
- Hyperbolic functions
- Elementary mechanics using vectors
- Energy
- Rudimentary analysis of continuous/smooth functions
- Elementary optimisation
- Some special functions (Gamma, Bessel), orthogonal polynomials
- Applications of complex analysis
- Fourier and Laplace transforms
- Partial Differential Equations
- Orthogonal curvilinear coordinate systems
- Fixed points of nonlinear ordinary differential equations
- Limits of convergence
- Basic coordinate geometry and graph sketching

Q23 and Q24: Respondents were asked to comment on some suggested topics for Level 3 statistics students and to suggest other topics that might be important. The suggested topics were:

- Algebra – particularly solving quadratics and manipulating functions
- Logs and exponentials
- Calculus – particularly integration
- Matrices
- Properties of statistical distributions
- Statistical modelling

These questions were answered by 20 respondents, with some others commenting that statistics was not their area of expertise. All the suggested topics were seen as useful, with calculus and algebra being mentioned most often. Hypothesis testing and the basics of probability were the most common additional topics. The additional topics suggested include:

- Probability
- Hypothesis testing
- Use of Log for ln
- Estimation and inference
- Notation ($\sum$ $\prod$)
- Use of software

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Q25 and Q26: Respondents were asked to comment on some suggested general topics for Level 3 mathematics and statistics students and to suggest other topics that might be important. The suggested topics were:

> - Good mathematical communication
> - Report or essay writing in mathematics and statistics
> - Precision in calculations

These questions were answered by 32 respondents. Most respondents thought these would be useful topics, though some felt that Level 3 students might not need them. Additional topics suggested included typesetting/LaTeX and how to write mathematics. The other suggestions include:

- Typesetting/LaTeX
- Effective use of graphs, tables and charts
- Referencing (e.g when referring to theorems and checking assumptions)

- Showing how modules relate to each other
- Use of software
- Writing mathematics
- Discussion areas e.g. getting students to work through a tricky problem or summarise a theory.

Q27. Do you have any other comments or suggestions that you wish to make about this project?

There were 22 additional comments from respondents. Most of these were reiterating support for the idea of a revise and refresh website for Level 3 students. For example: "I think this is a great project. Anything that can help students develop their love for maths is fine by me."

Queries included how easy it would be to find the resources and have time to use them, especially for students registering near the final enrolment date.

Further suggestions included access to tutors, software and discussions as well as how to organise the material. One suggestion was to list each topic and say which modules it is essential for, useful for and not relevant for.

Activities: Creation of Revise and Refresh Website for transition between level 2 and level 3

Based on the feedback from Associate Lecturers survey, and using ALs experienced in the appropriate level two and three modules we created a suite of websites and resources that allow students to self-identify address gaps in their mathematical and statistical skills.

From the responses it was apparent, that whilst all modules would benefit from a revise and refresh site, some disciplines within maths and stats relied much more on pre-requisite material than others and therefore each revise and refresh site would be slightly different, however in most cases it was possible to create a site for the discipline, thus adding to the familiarity of the sites and increase the number of students that would be looking at one site, creating a community of, for example applied maths students. It is the intention that these sites can be added to and adapted as required and

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particularly when new modules are released, to ensure students continue to receive the most effective support.

Whilst the format of each site may be different, the starting point where students access the resources is always identical and so will be familiar for all students. Every module in maths and stats has a "Discover your module" page, and in the right-hand box are the links to the revise and refresh materials as shown below for M347: Mathematical statistics (M347).

Figure 7: Mathematical statistics "discover your module" page, indicating position of revise and refresh resources.

The titles in the right-hand box, which indicate the key topics to study before module start, arose from the Al survey and conversations with Als that compiled the resource material and form links that take you to the sites containing the revision material.

For the disciplines of applied maths and statistics these sites are similar. Both subjects rely heavily on a knowledge of pre-requisite material and students need to practice plenty of questions in order to gain an understanding of this material. For applied maths, the revision material is based on both MST224 or MST210: Mathematical methods, models and modelling (MST210), all students that start level 3 applied maths modules will have studied one of these modules, but not both. For Statistics the revision material is based mainly on M248: Analysing data (M248), however, as was noted by the ALs, students also have a need to revise basic maths, particularly algebra, functions, exponentials and logs and therefore students were also directed to the key parts of the revise and refresh for MST124 website.

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Each title in the right-hand box takes the student to a page containing a table where the rows display several sub-topics. Not all sub-topics are required by all modules and so the table indicates, firstly whether the module requires the sub-topic and secondly, if it is required, whether this knowledge is essential or desirable. This is shown in figure 8 below, where a blank box indicates that it is not needed, a green mark indicates it is essential and a purple mark that it is desirable.

Figure 8: Example of a revise and refresh subtopic page.

Underneath the table, the applied mathematics pages offer a PDF of questions to practice for each sub-topic and the statistics pages indicate which M248 practice quizzes the students should attempt. This will give an indication for the student of which topics need further study and the references for these can be found in the right-hand box.

The preparation needed for pure maths modules slightly different and so the format of the right-hand box taking the student to a table of all pure maths modules is not appropriate, instead each module has its own site. The sites for M337: Complex analysis (M337) and MST368: Graphs, Games and designs (MST368) are formatted similarly and the titles in the right hand box of the discover your module page takes students to a list of sub-topics with references to the appropriate module material and a set of practice questions underneath, however each module has different prerequisites, with M337 pulling material from MST124, MST125: essential mathematics 2 (MST125) and M208 and MST368 from only MST124 and MST125. M303: Further pure maths (M303), builds solely from M208: Pure maths (M208) and so the right-hand box on the discover your module page will take the student directly to documents that reference the M208 material and is split into

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introductory, core and further material, although only the introductory and core material are needed to prepare for M303.

Findings: Student use and feedback of revise and refresh sites

It is hard to analysis the use of these websites as they are available to all students with a PI and so are often viewed by students who are just looking at which modules they might want to study next, rather than preparing for a module they have already committed to study, however an indication can be gained by looking at the forum that is associated with the discover your module site as many of these questions are linked to the prerequisite material and revise and refresh. This is a forum that is monitored by an experienced maths and stats associate lecturer, which will pass the query on to an appropriate member of staff if they don't know the answer themselves. As can be see from the graphs below, during the first 2 years of use, throughout the 3 months, August to September, the forum is consistently used with between 130-180 posts in each year.
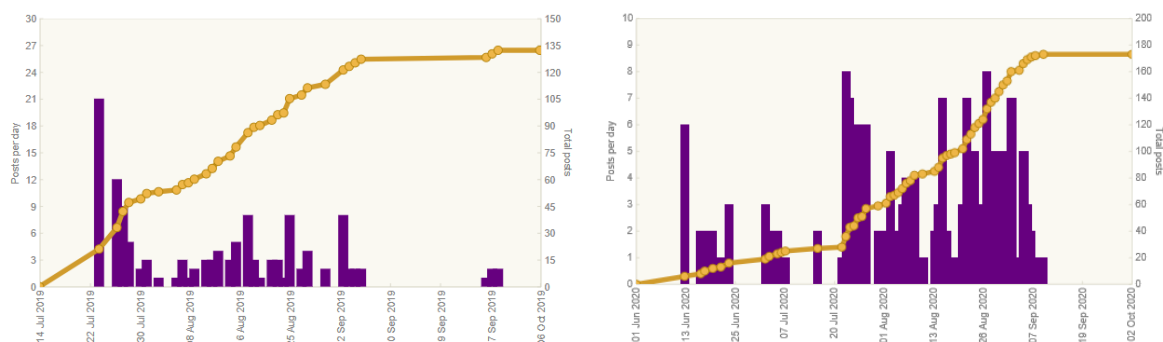

Figure 9: graphs representing the forum usage for the pre-module help forum during the summer period July – September for 2019 and 2020.

Further feedback on the revise and refresh sites has been gathered from students during analysis of the maths and stats study site, in the eSTEeM project "The mathematics and statistics community of learners", project lead Rachel Hilliam; In this project, questionnaires were sent to a sample of students and staff that may have interacted with the maths and stats study site. One of the questions asked them to rate how useful they found the revise and refresh resources, of the 50 students that answered the question, eight had not used the revise and refresh sites, fie had found them slightly useful, 16 found them quite useful and 21 had found them very useful.

The School of Physical Science was impressed by the revise and refresh sites they used them as a model when designing their own pre-module study sites.

Output

As well as the revise and refresh sites, the following dissemination on the project was given:

Scholarship across the faculties: From Creativity to Innovation 2020

October 2020 Presentation "Supporting the student's learning journey through the transition of mathematics and statistics from level 1 to level 2. Susan Pawley and Alison Bromley.

STEM teaching conference 2020

Feb 2020 Presentation: "Revise and Refresh: out of module support" Susan Pawley

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Poster presentation, eSTEeM conference 2017

Bromley, A., Hilliam, R., Hughes, C., Pawley, S. (2017) *Supporting students' learning journey through the transition between levels in mathematics and statistics*. eSTEeM conference

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Appendix 1:

17. Please describe any other types of resources you think may be useful for students preparing to study Level 3 mathematics and statistics modules.
Access to the relevant prerequisite material from Level 2. I know this is already standard practice, but it might be helpful to distill this material into a resource which is particularly salient for the Level 3 module.
Links to additional resources on problem topics eg external or text books.
Introductions to topics would be useful to students studying outside there past experience. For example on M337 there are always a few students that seem to have never met complex numbers before (or at least don't recall them) and find the speed that the basics are run through in units A1 and A2 is fast. I'm not saying that M337 needs to change just we need to help students who have the missing knowledge to gain it.   I think that the modular approach taken to maths is great (I loved it when I was an OU student) but perhaps there could be some material available drawing everything together. Showing links between the various modules and also how they are used in academia, post-graduate study and other employment. Perhaps some idea of active research areas would be useful too.
Recordings of tutor-led online problem classes
Screencasts Summaries of previous modules
Specific "Prepare to study <module code>" materials which focus on the essential prerequisites for that module which a student needs to have at their fingertips when starting the module. This is more important than generic "Prepare for Level 3" materials.
Conceptual understanding of key calculus concepts. Too many students blindly follow procedures in the handbooks and don't really understand the topics. This means they aren't ready for third year study.
1) Previews of early material from level three modules.   2) Animations and screencasts for selected topics and techniques (to aid understanding rather than just technical mastery through repetition of exercises).   3) An archive of old BBC / OU maths module programmes (if any of the lecturers who are still working don't mind people seeing them in tank tops and kipper ties)
With topic summaries, etc good references back to the Level 2 module materials.   Resources to help with/revise any software (eg Maxima)
Weekend day schools.
Some sources from students who studied Level 3 courses in the past, such as a forum for students from different levels
Links between modules. For example, "compact" and "connected" are used in M337 and M303, but have somewhat different meanings. That's tricky, since there's no required order of study, but a comparison table could be used. Also, concepts in M208 are used in M337 and M303, but are not related (limit points in M337 vs punctured neighbourhoods in M208). Almost all continuous functions in M208 are Lipschitz, etc. Lists of material needed would be useful (quotient groups from M208 needed in M303, comparison of notation for sequences, etc.). M303 makes heavy weather of generalising distance and analysis from R to Rn, and it seems pretty obvious to me - there are much more important concepts to get across.
short videos 5-7 min online tests for different topics
small group face to face tutorials
Access to computer resources they will be using e.g. the stats packages and some introductory examples using the package so that they can get up and running with the IT well before the module starts.   It would be good to have some advice/case studies about career options and choice of modules so that students have time to make good decisions about their study plans and make any changes.

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I think there is a big step up in mathematical thinking from Level 2 to Level 3, it depends on exactly which route you take and on the Level 3 course involved but having resources that really work on mathematical reasoning and communication. This is especially true for M303 even with improvements after the disastrous first year but I think covers all Level 3 M&S courses.

It is not clear to me what is meant in the previous question by "exercises". It could be indicative of thinking that all students need are techniques. In fact what is needed more, in my opinion, is a development of level 3 "mathematicality", not least modelling skills.

Worked examples presented as screen-casts. Worked examples demonstrating more theoretical ideas as well as methods.

Thorough revision of computer algebra in particular Maxima.

students sometimes ask me to recommend textbooks covering course prerequisites, so that they can see the topics explained in multiple ways and revise things they're unsure of before the course start date.

Actual examples of level 3 questions with the level 2 working highlighted. In my experience it is a big step to go from "being able to integrate an equation" to "solving a problem which requires integration of an equation along the way"

Module choice advice? though probably needs SST input. Maybe some recorded multimedia package detailing module relevance to career targets: industry/finance/government/academia etc.

Accepting that students may have varying backgrounds when embarking on level 3 - the 3 main problems are: (1) insufficient knowledge; (2) not yet developed study skills to be sufficiently independent and self-resilient mathematically speaking (e.g. coping strategies for when you get stuck); (3) constructing solutions. So for (1) list of topics needed to start the module plus diagnostic quizzes for each topic. Then access to necessary material e.g. MST125 Units 3 and 9 for say M303, Unit 12 for MT365. For (2) help from a tutor, online sessions, and a designated website. For (3) additional help from website and tutor led sessions.. also may be material at level 2 that helps. We had some good material in M101 about this - specializing, generalising etc. Unit 9 in MST125 and communication stuff in MST124. Also could include what's expected re academic conduct, avoiding plagiarism.

On M303 students had 'Exam-like practice quizzes' which seemed to be seen as a useful part of their overall revision. Early feedback from (admittedly small) sample of students was very positive.

Some students have forgotten the basis rules of calculus - eg: differentiating a function of a function, so some revision in that area might be useful. An M373 student recently found difficulty in using a calculator effectively, so some revision would help.

It would be very useful to keep and develop 'bridging material' for students that are a bit rusty at level 2 as many level 3 students are ill-prepared. Also, interactive applets would be very good (like the ones in the level 1 modules). So, for say M337, you could have different complex functions that the student could change (or even define) and you could then see what the effect of a Cartesian or Polar Grid in the plane would be under these functions. Complex Analysis would greatly benefit from visual apps like this where the parameters can be altered in real time.

Short Screencasts with a tutor demonstrating a standard technique or explaining a concept.

Calculus, especially integration

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Appendix 2

18. Please describe anything you feel the University currently does that detracts from students being able to prepare for Level 3 mathematics and statistics modules.
It would be useful at registration that students have the requisite knowledge from Level 2.
I think helping students see how their studies link to current research may be helpful with motivation. Perhaps central academics from Walton Hall could write brief articles about their work.
Spoonfeeds them at Level 2!
Too much spoon feeding of information. Students often given model answers to questions and have underdeveloped problem solving skills. Lateral thinking and proving results is not really taught or tested.
It's more a question of inaction. There is a lack of encouragement and guidance to make weaker students recognise and adress the realities ot taking on L3 maths studies.
It's more what it doesn't do! It has no material relating one module to another. It doesn't flag up students who did (say) MS221 rather than MST125, or students did M208 many years ago, so they must be rusty.
Lack of contact during periods when the student is not studying
possibly overloads students with too much material at the beginning of a modules
I think that dealing with each module very separately perhaps makes it harder for students to see how the different topics relate to each other. There isn't a lot of advice for students about how to make good choices about which modules to study together e.g. avoiding two very demanding modules in the same year or conversely choosing modules that might complement each other.
it can be hard to find relevant revise and refresh material
I think we could do with some *slightly* harder TMA questions towards the end of Level 2 modules that work on communication and reasoning, a lot of students get to Level 3 and expect to be able to just apply the results and methods by exactly the same means, which is not the case at Level 3 (with the possible exception of M343).
I don't know about the preparation phase, but there's not much done about modelling within M343, for example. Now that TMAs are formative, perhaps they could be used, at least in part, to plug this gap? It would not require that much imagination!
Lacks clarity in the general level, understanding and fluency of computer algebra required at level 3 even though this varies from module to module.
It's in the nature of the OU and the course structure that students will sometimes come to level 3 statistics after quite a long period of doing pure maths, or just after a break from study. I think dedicated revision materials would help build confidence more than the current advice to go back over other course materials - I don't teach any lower-level stats courses so can't direct them to specific parts of the earlier courses.
Taster units are always the first easy ones - students cannot use the summer to "get ahead" easily. Students should be able to receive online access early if they register early.
Having a tutor allocated just before the start of the module. Students may need to prepare in advance of this and may need help.
LEM and GTP
Sometimes students are ill-prepared for level 3 modules and so defer/withdraw quickly. Adequate checks need to be made to make sure students will be able to cope at level 3.
M208 uses a lot of "strategies" with step by step instructions, rather than helping students to develop the thinking skills they will need at Level 3. Often students are stumped and aggrieved it they can't find an example just like their assignment question in the study materials.

Bromley, A., Hilliam, R., Williams, G., Arrowsmith, G., Siddons, A. and Pawley, S. (2023) Supporting the student's learning journey through the transition of mathematics and statistics from level 2 to level 3. eSTEeM Final Report.