Learning behaviours and successful outcomes in STEM students

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Learning Innovation, Learner and Discovery Services

Executive Summary

Since 2016 the Learning Innovation team has been engaged in a series of research activities designed to gain a deeper understanding of the underlying study habits and learning behaviour of OU students, in order to inform the future development of pedagogy, systems, tools and platforms. Potential student behaviours related to study were tested and validated in 2017, as reported in 'A survey of the learning behaviour of Open University students' (Ellis et al, 2018). Through a process of Principal Component Analysis, seven clear learning behaviours were identified.

These learning behaviours are Goal-setting, Time, Focus, Note-making, Digital-preferred, Help-seeking and Elaboration.

Although the 2017 dataset included students from across OU faculties, there was a preponderance of Arts students. Therefore, in Spring 2019, the survey was repeated with a small group of students from Science and Technology modules. Through an analysis of these results, including a comparison against previous samples, differences were observed between the behaviour of STEM and non-STEM students. The causes of these differences could potentially include the learning design of STEM modules.

With this in mind ESTEEM, the STEM scholarship centre, was approached to fund a project to focus specifically on learning behaviours of STEM students. The aims of this year-long project were:

- To investigate the relationship between the learning behaviour of students and outcomes within the context of modules in presentation.
- To gather learning behaviour data from individual students and cohorts from selected Level 2 STEM modules, to provide a baseline as well as a triangulation point for determining the relationship between learning behaviours and student outcomes.
- To conduct an in-depth module mapping of each module using the emerging Learning Behaviour Framework, Learning Design Online tools and Nvivo.
- To compare the learning behaviours of the 2020 cohort of OU students with their outcomes and establish correlations between these.
- To rigorously test this by revisiting the 2017 student dataset (Ellis et al, 2018) and re-examining the learning behaviours of that cohort with their subsequent outcomes.

The project reached three conclusions, each of would have an impact on learning and teaching at the OU:

1. That students who demonstrate learning behaviours could be likelier to progress.
2. That relationships exists between Learning Behaviours, and that certain behaviours appear to trigger each other.
3. That Learning Behaviours are present in the learning design of modules and could trigger specific behaviours in students.

Contents

Introduction

Since 2016 the Learning Innovation team has been engaged in a series of research activities designed to gain a deeper understanding of the underlying study habits and learning behaviour of OU students, in order to inform the future development of pedagogy, systems, tools and platforms. 'Study behaviours in an increasingly digital world' (Ellis et al, 2017) uncovered themes that could be linked to the behaviour of students as they study and learn. Eight potential behaviours and attitudes were identified at that time.

These behaviours were subsequently tested and validated in 2017, as reported in 'A survey of the learning behaviour of Open University students' (Ellis et al, 2018). Through a process of Principal Component Analysis, seven clear learning behaviours were identified.

GOAL Goal-setting

A student with a high GOAL score tends to set goals and plan. All the contributing statements, listed below with their abbreviations, describe student behaviours. The statement abbreviations are useful for understanding the PCA results.

A high score on these statements contributes to a high GOAL score:

I set goals to help me manage study time for my learning.	time goals
I set short-term (daily or weekly) goals as well as long-term goals (for the whole module).	short long goals
I set realistic deadlines for learning.	deadlines
I plan each study session to work on a specific task.	session task
I set personal standards for performance in my learning.	personal standds
I plan my study to match the needs of the assessment.	plan assess
I make good use of my study time.	good use time

TIME Time

Students with a high TIME score prioritise time to spend studying. They tend to keep to a study schedule and keep up with the work for the module. This concept has aspects of time-management ability, although the statement about 'other activities' touches upon some factors that may be beyond the student's control. For example, other activities may be childcare or employment.

Note that some questions relating to TIME asked about negative factors ('no time to review' etc.), so those contribute a negative value to the TIME score. For example, a student who responded 'Very true for me' to the statement 'I find it hard to stick to a study schedule' scores minus 5 towards the TIME concept.

I often find that I don't spend very much time on my module because of other activities. (negative)	other activities
I rarely find time to review my notes or readings. (negative)	no time review
I find it hard to stick to a study schedule. (negative)	hard stick sched
I make sure that I keep up with the readings and assignments for my module.	keep up

FOCUS Focus

A student with a high FOCUS score tends to avoid clutter and distraction, including online. The statements generally relate to behaviours, although 'I have a regular place set aside for studying' could be an environmental factor. Not all students have a regular place due to their living or working situation, for example someone in a busy family home, or someone who travels extensively for work. This new concept includes aspects of the original themes 'digital as distraction' and 'digital as clutter'.

I usually choose to study in a place where I can concentrate on my course work.	concentrate
I avoid websites that are cluttered with many features on each page.	avoid clutter
When I want to concentrate, I avoid communicating with other students online (forums or social media).	avoid online
When I study online, I mainly use the OU module website.	mainly OU
When I want to concentrate, I only open the webpages I need for studying.	only web I need
I have a regular place set aside for studying.	regular place

NOTE Note-making

A student with a high NOTE score tends to make notes. This concept includes physical storage of notes. Digital storage of notes is included in the concept 'digital preferred'. The two statements about reading guidance for assessment on paper or digitally cover both digital and physical media, with different signs. A preference for reading assessment guidance on paper will contribute to a high score for NOTE.

I make handwritten notes as I study material for the first time.	handwrite notes

I read my own notes mainly on paper (handwritten or printed out).	read note paper
At the end of my module, I will physically store the notes and work I have written (on paper including printouts).	store physical
When I am studying, I make a note of where to find information I will need for the assessment.	note assess
When I am studying material for the first time, I make a note of sections I want to come back to later.	note to return
When I am working on an assessment, I read the questions and guidance on paper (including printouts).	assess paper
When I am working on an assessment, I only read the questions and guidance on screen (no paper or printouts at all). (negative)	assess digi

DIGI Digital-preferred

A student with a high DIGI score tends to use digital technologies or media. The survey explored alternative media and technologies for carrying out tasks. Use of digital technologies is the main feature of this concept. This may be instead of physical technologies, or in addition to them.

I make digital notes as I study material for the first time.	digi notes
I read my own notes mainly digitally (on screen).	read note digi
I use a digital tool or digital document (on screen) to plan my goals.	digi goal
I use a digital tool or digital document (on screen) to organize my study time.	digi organize
At the end of my module, I will digitally store the notes and work I have written (on screen).	store physical

HELP Help-seeking

A student with a high HELP score tends to connect with other people for support with their studies. Help-seeking may be online or face-to-face and may include peer or OU support. This is about connecting with other people to support study. A student who prefers to work alone would have a lower HELP score, as that statement has a negative contribution.

When I do not understand something, I ask others for help.	ask help
I ask others for more information when I need it.	ask info
I try to identify others whom I can ask for help if necessary.	identify helpers
I ask for help from other students online.	ask online
Even if I am having trouble learning, I prefer to do the work on my own. (negative)	prefer alone

ELAB Elaboration

A student with a high ELAB score tends to seek information and relate new ideas to ones already known. This concept includes aspects of the original theme 'digital seeker', which was about looking for information online. Elaboration is primarily about information. In contrast, help-seeking is about people.

I try to apply my previous experience when learning.	apply exp
When I am learning, I try to relate new information to what I already know.	relate new to old
When I am learning, I combine different sources of information (for example: people, websites, printed material).	combine info
When I am learning, I look for information online beyond what is available from Open University websites.	beyond OU

In addition, using features from the OU's Digital and Information Literacy Framework, Technological Self-Efficacy was identified as a related skill.

Students display these seven learning behaviours and their Technological Self-Efficacy while studying, with varying degrees of intensity.

Background to the project

Although the 2017 dataset included students from across OU faculties, there was a preponderance of Arts students. Therefore, in Spring 2019, the survey was repeated with a small group of students from Science and Technology modules. Through an analysis of these results, including a comparison against previous samples, differences were observed between the behaviour of STEM and non-STEM students. The causes of these differences could potentially include the learning design of STEM modules.

With this in mind ESTEEM, the STEM scholarship centre, was approached to fund a project to focus specifically on learning behaviours of STEM students.

The aims of this year-long project were:

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Methodology

Sample

A request was made to Student Data and Analytics for a representative cross section of students from S217 (Physics: from classical to quantum), S215 (Chemistry: essential concepts), T219 (Environmental management 1), TM254 (Managing IT: the why, the what and the how) that would allow the research team to receive 300 clean, complete responses, in order to be able to repeat a Principal Component Analysis.

The research team had permission to include additional demographic variables such as gender and specific needs markers in the interrogation of the data and explore the diversity of the results in this way.

Data and Student Analytics drew as diverse and representative a sample of student from the four modules in this research project as possible. However, due to low populations of students on the selected modules, the sample was both smaller and less diverse than hoped. In total 398 students were approached, with 37 responding to the survey (a response rate of 9.3%).

Of these, 27 respondents to the survey volunteered to be considered for experience sampling and an interview. Due to the high anticipated attrition rate, all 27 students were approached for an interview. Six students were interviewed in total, however only 4 were recorded and transcribed and included in the analysis.

University approval processes

- SRPP/SSPP – Approval from the Student Research Project Panel/Staff Survey Project Panel was obtained according to the Open University's code of practice and procedures before embarking on this project. Application number SRPP 2019/136

- Ethical review – An ethical review was obtained according to the Open University's code of practice and procedures before embarking on this project. Reference number HREC/3434/Ellis and HREC/3570/Ellis
- Data Protection Impact Assessment/Compliance Check – A Data Protection Impact Assessment/Compliance Check was obtained according to the Open University's code of practice and procedures before embarking on this project. Data protection approval was received for holding the sample of student data for the interview, their survey responses, as well data generated by experience sampling and interviews (13/11/2019)
- Data protection approval and SRPP advice was also sought to ensure retrospective analysis of 2017 dataset could be done, and the outcomes data for those students was provided by Data and Student Analytics.

Impact of Covid-19

The original schedule for the research required two sets of surveys (during the module and after the module) and the intention was to build a longitudinal picture around this. The research team also hoped to conduct three experience sampling events leading up to the post-module interview. In addition, we intended to undertake a direct analysis of the students' responses and their assessment results.

Aside from being unable to conduct a PCA due to small populations and low response rates, COVID-19 and the changed assessment strategies to respond to the crisis led the team to cancel both the additional experience sampling sessions and the second survey point.

This was replaced by a single experience sampling question and an interview schedule through June and July in order to accommodate and acknowledge the disruption our students' lives. COVID-19 also had an impact on the qualitative data collected during the interview.

Process

The original goal for analysis of the survey data was to conduct a principal component analysis, but population on the modules initially identified for this project were too small to be able to do this. Instead, a method of investigating the learning behaviours of students was devised based on Christiernin (2010), which allowed for individual student results to be calculated and displayed using a 'spider gram' or 'radar diagram'.

These diagrams offer a way of displaying and visualising different students' separate learning behaviours and skills, the distribution of these behaviours and skills across a cohort, and then offers the opportunity through visual inspection to be able to able to identify prevalent patterns of behaviour.

Where radar diagrams have been created to display learning behaviours, we call these R-Profiles. They differ from personas, which display averages or archetypes of behaviour. R-Profiles instead

display individual responses. This can have a crucial impact on the learning design of modules, because they display what students report they do while learning.

Analysis of the data resulted in a variety of R-Profiles. The prevalence of certain behaviours and patterns of behaviour supports the impact of effective learning design.

Analysis

Survey

In total 398 students were approached, with 37 responding to the 'Learning Behaviours of STEM students' survey (a response rate of 9.3%). The survey consisted of the original 55 behavioural and attitudinal statements from the 'Learning Behaviour of OU students' survey (Ellis et al, 2018), with one additional question designed to understand what format assignments consisted of and were submitted in. This question was added in order to differentiate the experiences of STEM students from other faculties.

Thinking about the assignments you have done so far on your current module, please provide rough estimates of the following, based upon the total number of pages of work you've submitted so far. What fraction of the total number of pages have been:

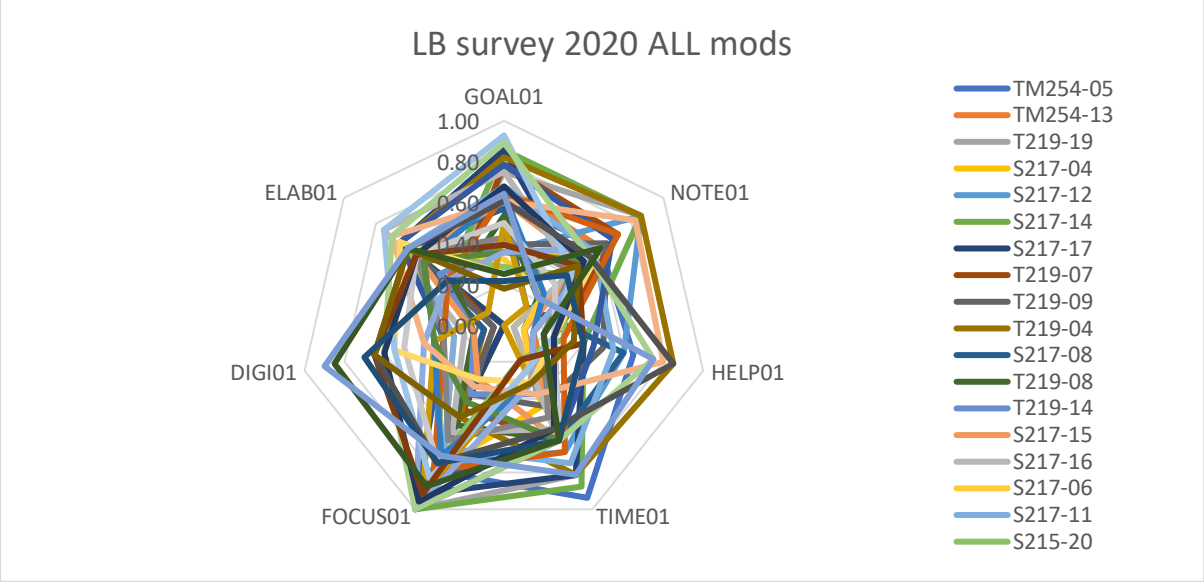
- diagrams, graphs or charts
- computer code
- mathematical notation
- written word

(Range: none, less than half, about half, more than half, all)

Profile types from 37 radargrams from 2020 surveys

R-Profile 1 is a representation of every response from the 2020 surveys (N=37), with each radar diagram representing the experience of an individual student.

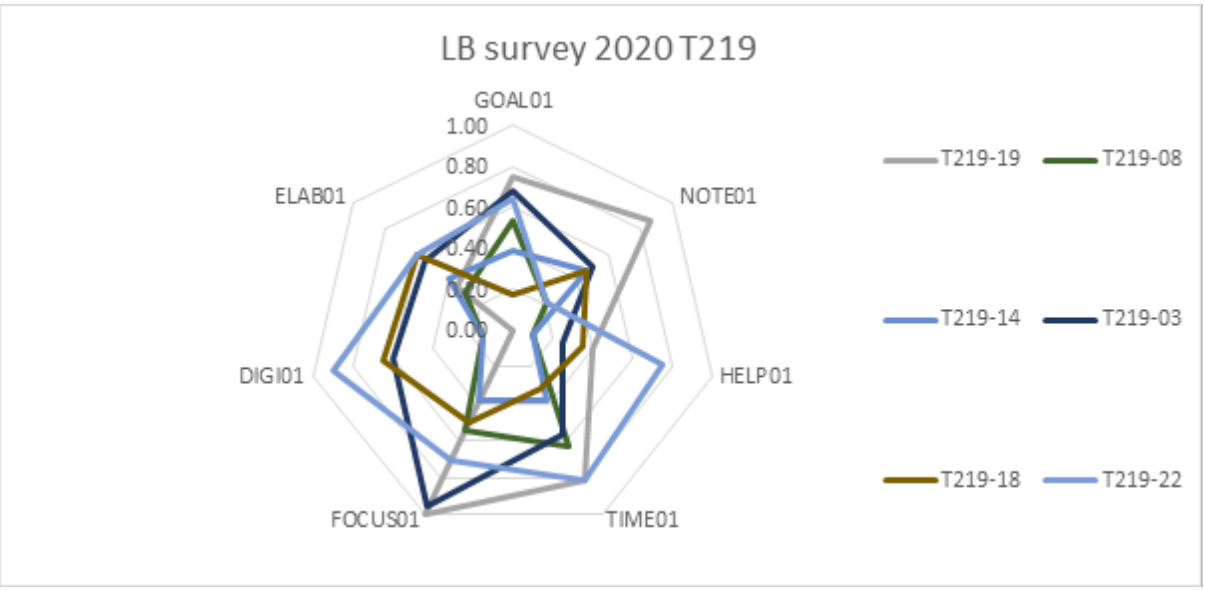
R-Profile 1



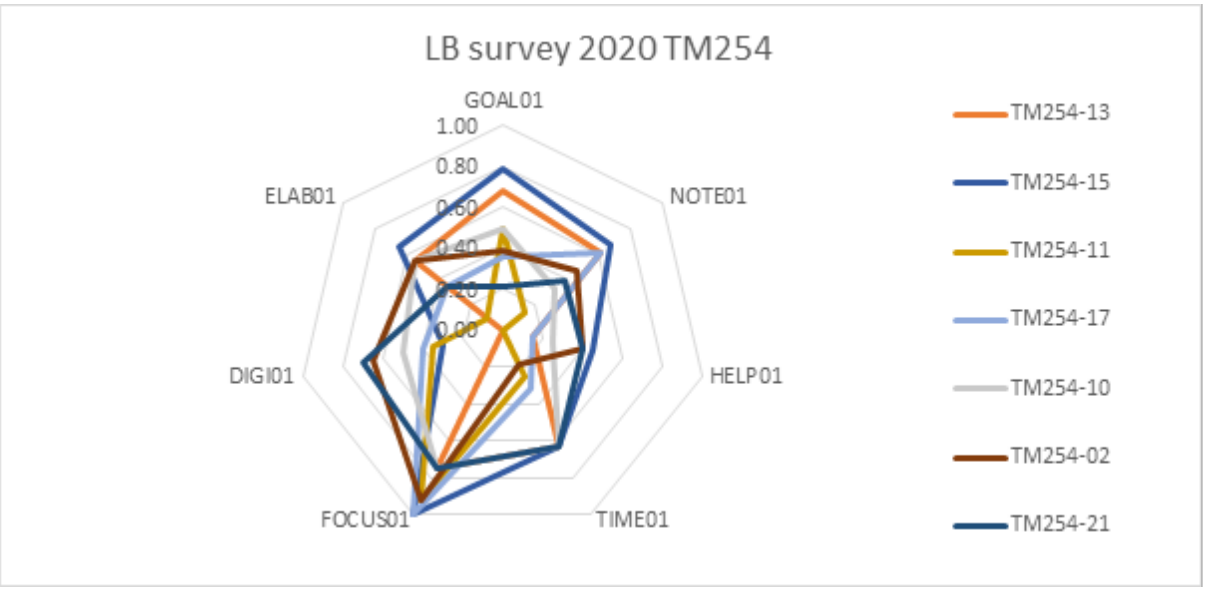
Each R-Profile series represents a student's learning behaviour profile, allowing for a visual inspection of similarities and differences between students on a single module, as well as students across modules. The similarities and differences can be explored to understand what encourages these, for instance ascertaining the impact of intentional module design on student behaviour, as well as unintentional impact on behaviour introduced through the design and production process.

R-Profiles 2 to 5 group participant responses by module.

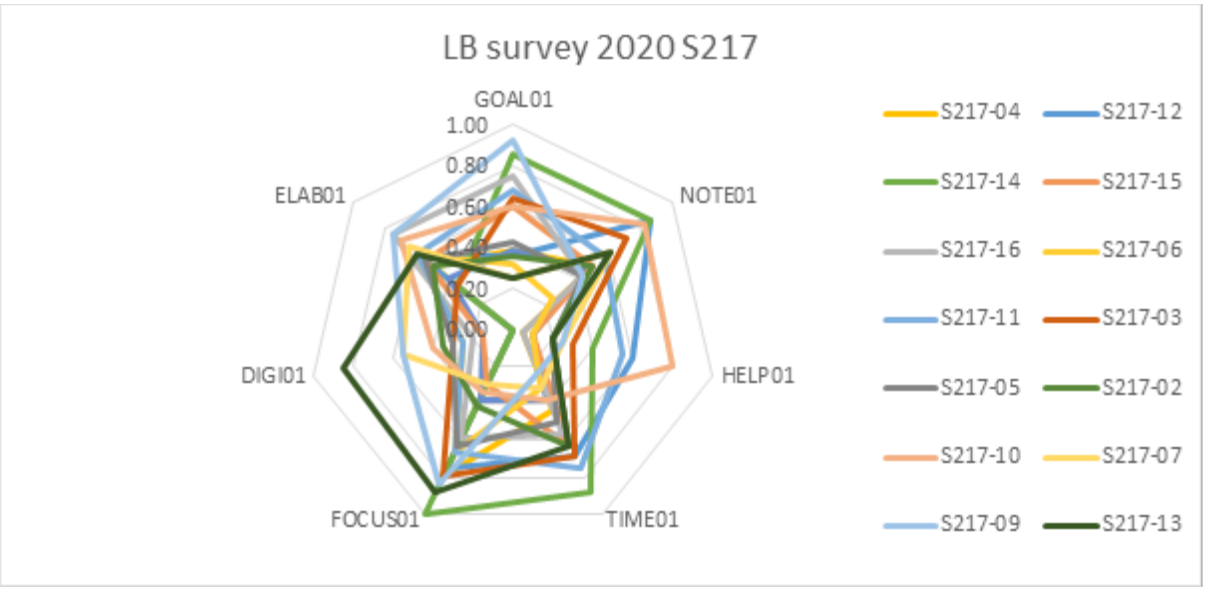
R-Profile 2



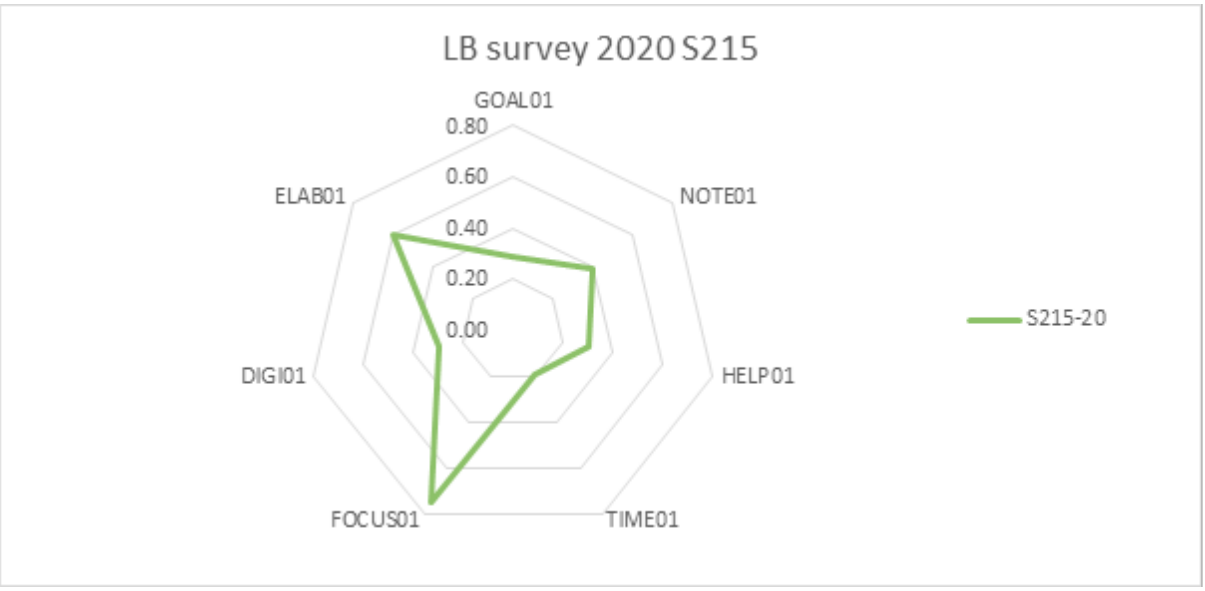
R-Profile 3



R-Profile 4

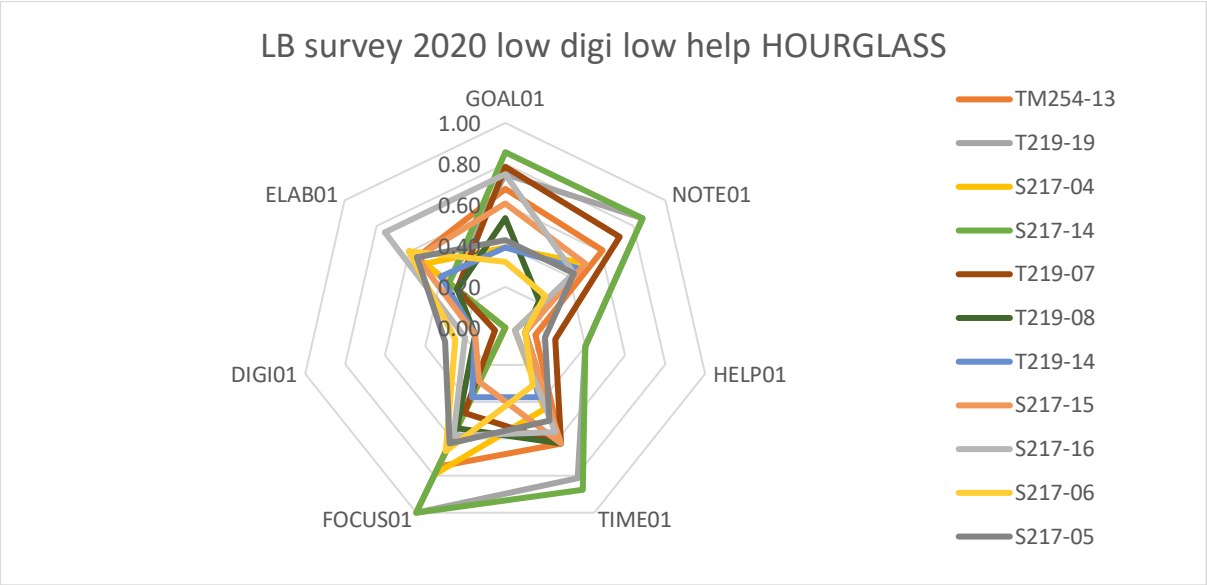


R-Profile 5

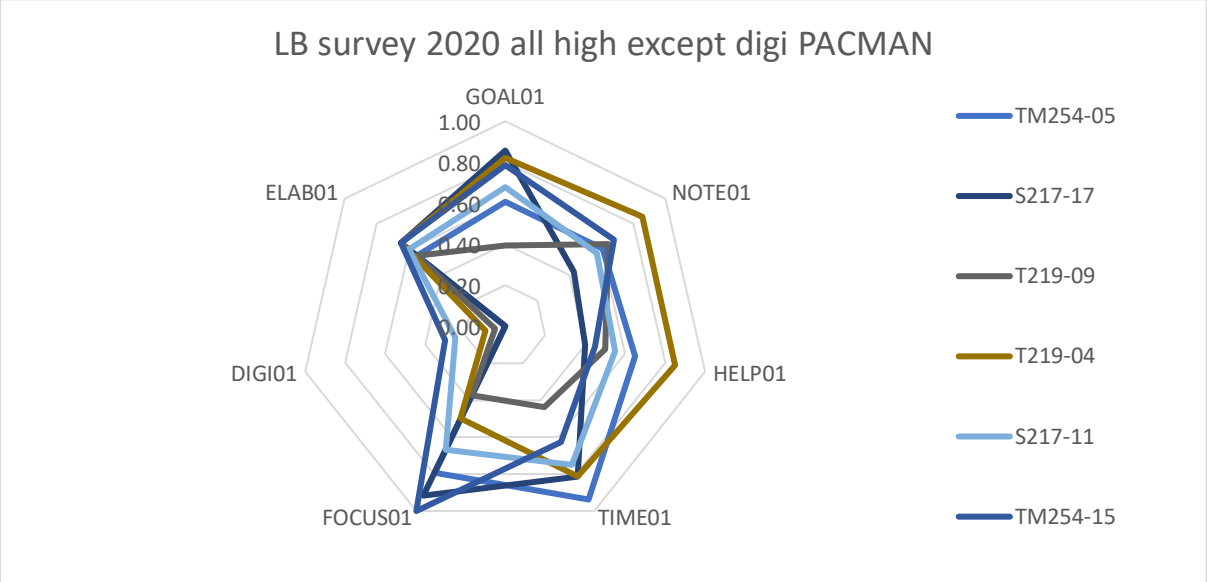


Using the visual examination process outlined previously, the data was sorted according to the similarities in shape of the R-profile. R-Profile 6 shows the largest group of students within the participant group, representing predominantly T219 and S217 student experiences, although it should be noted that S217 was the module that received the highest survey response. R-Profiles 7-12 demonstrating further that students exhibit individual learning behaviours, but that similar patterns can emerge.

R-Profile 6


LB survey 2020 low digi low help HOURGLASS
GOAL01
1.00
0.80
0.60
NOTE01
HELP01
TIME01
FOCUS01
DIGI01
ELAB01
TM254-13
T219-19
S217-04
S217-14
T219-07
T219-08
T219-14
S217-15
S217-16
S217-06
S217-05

R-Profile 7


LB survey 2020 all high except digi PACMAN
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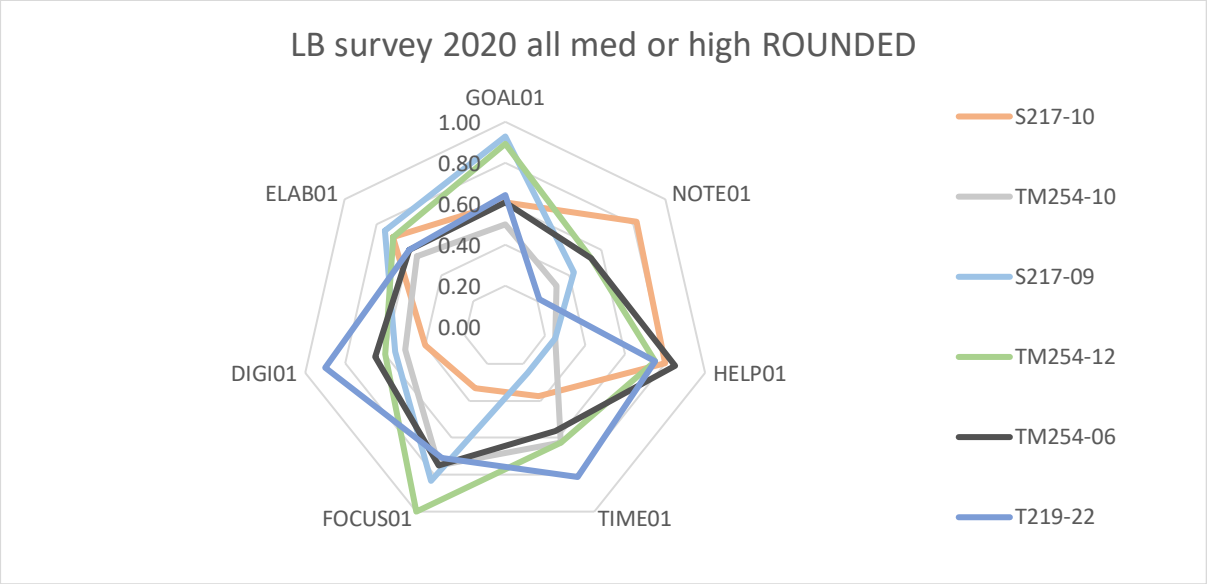
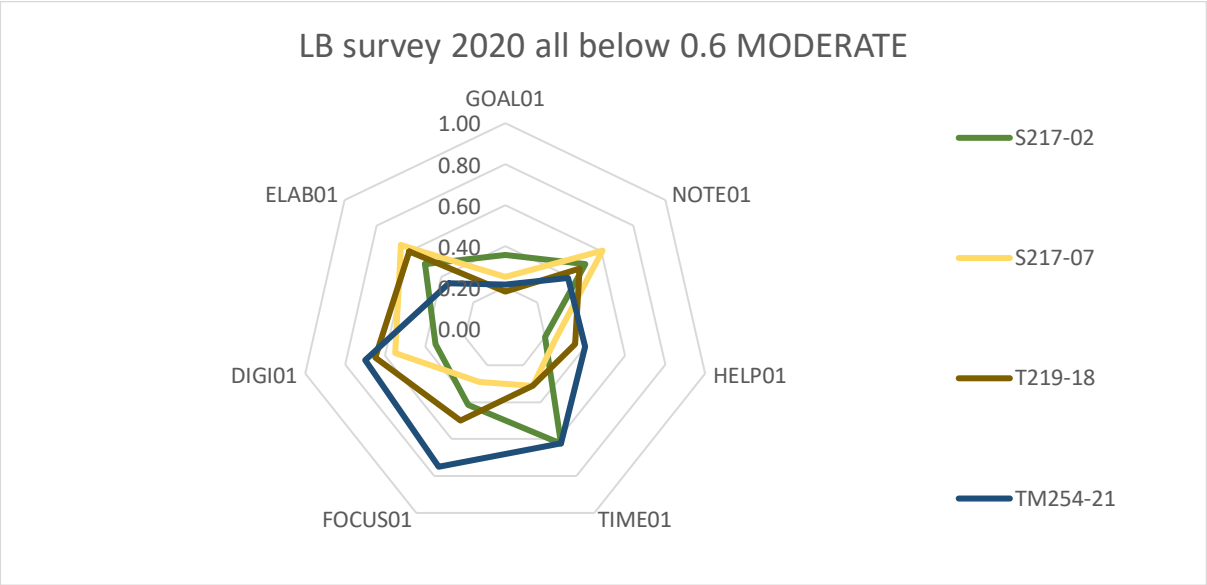
S217-17
T219-09
T219-04
S217-11
TM254-15

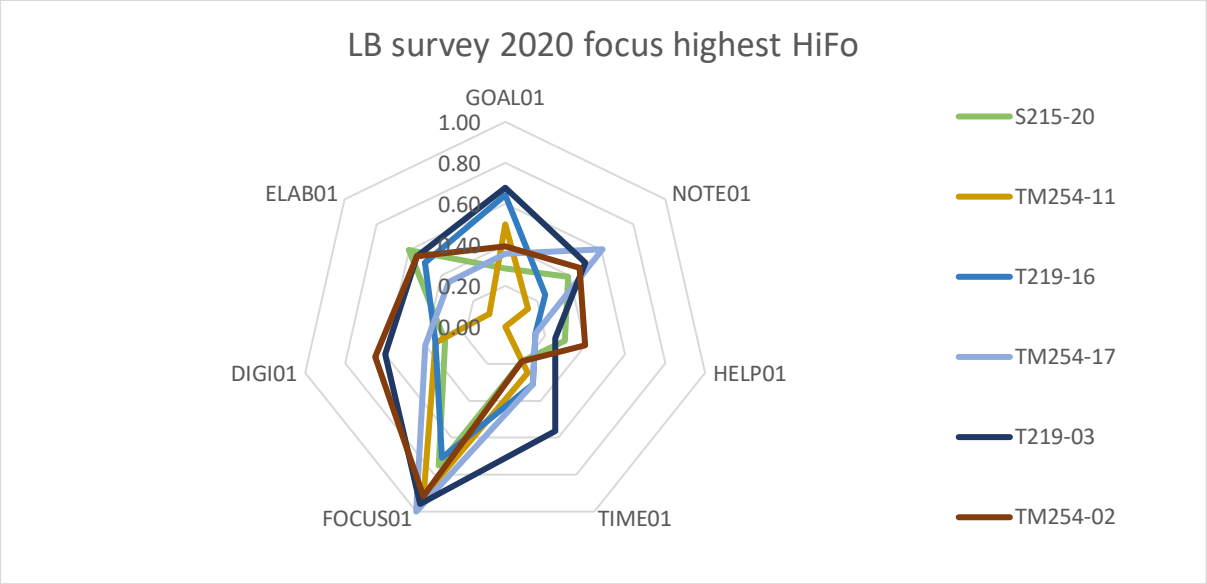
R-Profile 8



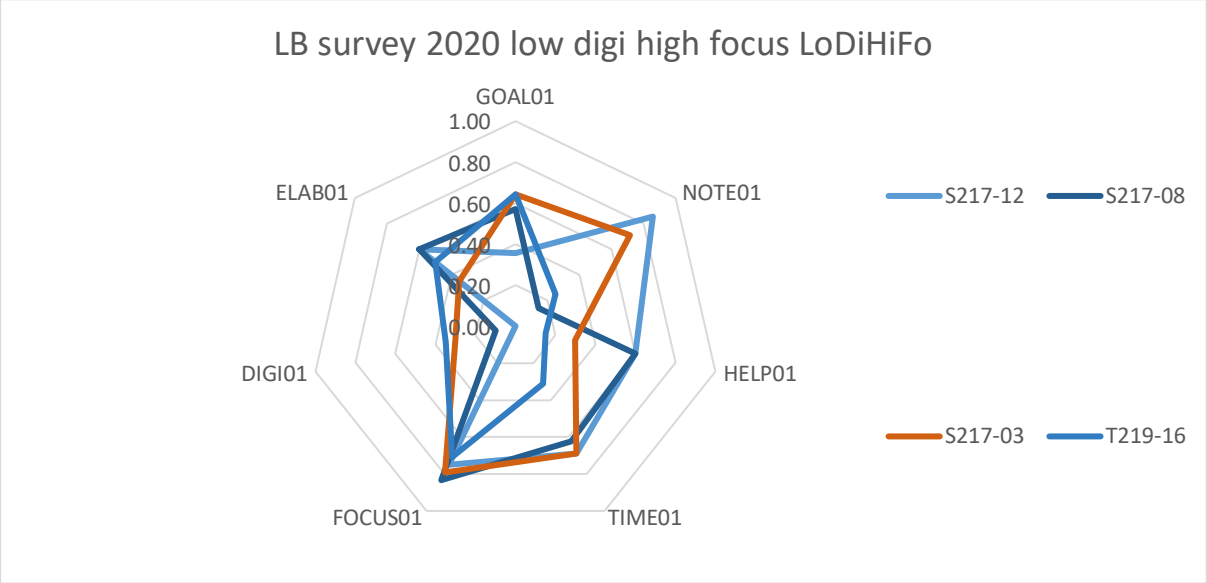
R-Profile 9



R-Profile 10



R-Profile 11



R-Profile 12

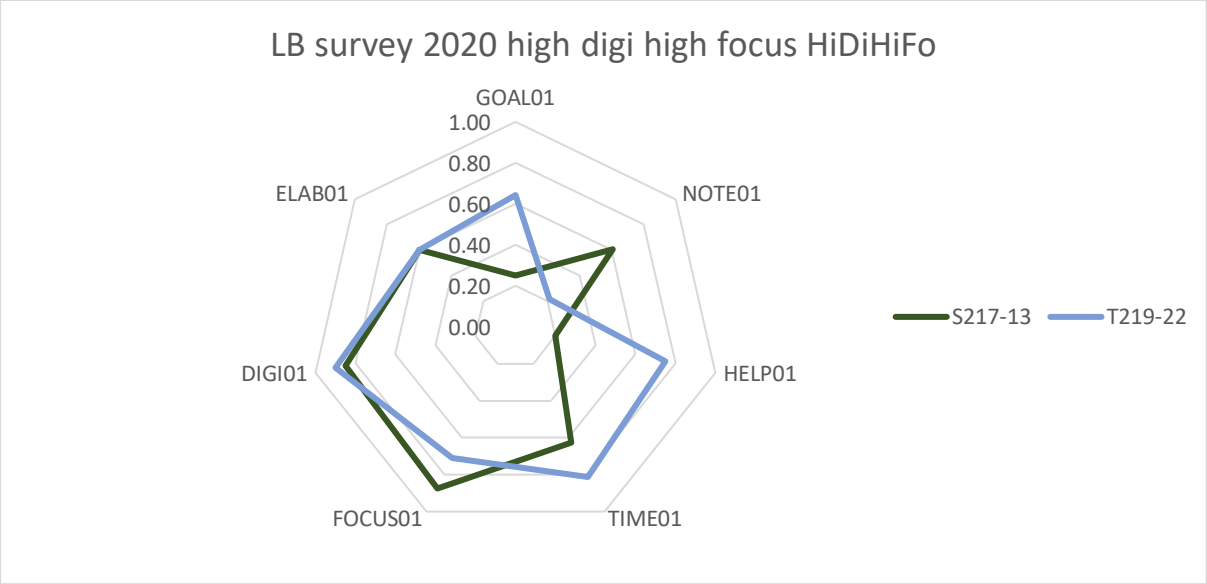


Table 1 represents the groups of students with similar R-Profiles, sorted by increasing DIGI scores. The survey data is too small to make significant claims about the impact of different behaviours on each from that dataset alone. However, similarities do emerge in that DIGI appears to be the behaviour subject to the most variation. Technological Self-Efficacy describes skills rather than behaviours and demonstrates a student's confidence in their ability to perform tasks from the OU's Digital and Information Literacy Framework. This is also less variable than DIGI (Table 2).

Table 1: All modules with profile codes, sorted by increasing digi

ID	GOAL01	NOTE01	HELP01	TIME01	FOCUS01	DIGI01	ELAB01	TechSE01	Profile
TM254-05	0.61	0.61	0.65	0.94	0.79	0.00	0.55	0.71	P
TM254-13	0.68	0.61	0.15	0.63	0.75	0.00	0.55	0.67	H
T219-19	0.75	0.86	0.40	0.81	1.00	0.00	0.35	0.24	H
S217-04	0.39	0.50	0.05	0.44	0.79	0.00	0.50	1.00	H
S217-12	0.36	0.86	0.60	0.69	0.75	0.00	0.60	0.48	LDF
S217-14	0.86	0.86	0.40	0.88	1.00	0.00	0.35	0.57	H
S217-17	0.86	0.43	0.40	0.81	0.92	0.00	0.65	1.00	P
T219-07	0.79	0.71	0.25	0.63	0.46	0.05	0.30	0.95	H
T219-09	0.39	0.64	0.50	0.44	0.38	0.05	0.55	1.00	P
T219-04	0.82	0.86	0.85	0.81	0.50	0.10	0.65	0.57	P
S217-08	0.57	0.14	0.60	0.63	0.83	0.10	0.60	0.67	LDF
T219-08	0.54	0.21	0.10	0.63	0.54	0.15	0.30	0.48	H
T219-14	0.39	0.46	0.10	0.38	0.38	0.15	0.40	0.67	H
S217-15	0.61	0.50	0.10	0.63	0.29	0.15	0.55	0.57	H
S217-16	0.75	0.43	0.05	0.56	0.58	0.20	0.75	0.90	H
S217-06	0.32	0.25	0.10	0.31	0.67	0.25	0.60	0.57	H

S217-11	0.68	0.57	0.55	0.75	0.67	0.25	0.60	0.62	P
S215-20	0.29	0.39	0.30	0.19	0.75	0.30	0.60	0.95	F
TM254-15	0.79	0.68	0.45	0.63	1.00	0.30	0.65	0.67	P
S217-03	0.64	0.71	0.30	0.69	0.79	0.30	0.35	0.76	LDF
S217-05	0.43	0.43	0.20	0.50	0.63	0.30	0.55	0.43	H
TM254-11	0.50	0.14	0.00	0.25	0.92	0.35	0.10	0.57	F
T219-16	0.64	0.25	0.15	0.31	0.71	0.35	0.50	0.76	F
S217-02	0.36	0.50	0.20	0.63	0.42	0.35	0.50	0.62	M
TM254-17	0.36	0.61	0.15	0.31	1.00	0.40	0.35	0.71	F
S217-10	0.61	0.82	0.80	0.38	0.33	0.40	0.70	0.81	R
TM254-10	0.50	0.32	0.25	0.63	0.75	0.50	0.55	0.86	R
S217-07	0.25	0.61	0.25	0.31	0.29	0.55	0.65	0.86	M
S217-09	0.93	0.43	0.25	0.25	0.83	0.55	0.75	0.86	R
TM254-12	0.89	0.54	0.75	0.63	1.00	0.60	0.70	0.76	R
T219-03	0.68	0.50	0.25	0.56	0.96	0.60	0.55	0.86	F
TM254-02	0.39	0.46	0.40	0.19	0.92	0.65	0.55	0.33	F
TM254-06	0.61	0.54	0.85	0.56	0.75	0.65	0.60	0.90	R
T219-18	0.18	0.46	0.35	0.31	0.50	0.65	0.60	0.71	M
TM254-21	0.21	0.39	0.40	0.63	0.75	0.70	0.35	0.57	R
S217-13	0.25	0.61	0.20	0.63	0.88	0.85	0.60	1.00	HDF
T219-22	0.64	0.21	0.75	0.81	0.71	0.90	0.60	0.86	HDF

Profile Key

Hourglass	H
Pacman	P
Rounded	R
Moderate	M

focus highest HiFo	F
low digi high focus LoDiHiFo	LDF
high digi high focus HiDiHiFo	HDF

Table 2 Technological Self-Efficacy of each group

Profile code	Sum of TechSE01	Count	Mean TechSE
F	4.19047619	6	0.70
H	7.047619048	11	0.64
HDF	1.857142857	2	0.93
LDF	1.904761905	3	0.63
M	2.19047619	3	0.73
P	4.571428571	6	0.76
R	4.761904762	6	0.79

Table 3 Learning behaviour boundaries for each group

Profile Key	Profile code	GOAL01	NOTE01	HELP01	TIME01	FOCUS01	DIGI01	ELAB01
Hourglass	H	not low	not low	low	not low	not low	low	not low
Pacman	P	not low	not low	not low	not low	not low	low	not low
Rounded*	R	not low	not low	not low	not low	not low	not low	not low
Moderate	M	med	med	med	med	med	med	med
Focus highest HiFo	F	not high	not high	not high	not high	high	not high	not high
low digi high focus LoDiHiFo	LDF					high	not high	
high digi high focus HiDiHiFo	HDF					high	high	

*Rounded must have at least one high value, to distinguish it from Moderate

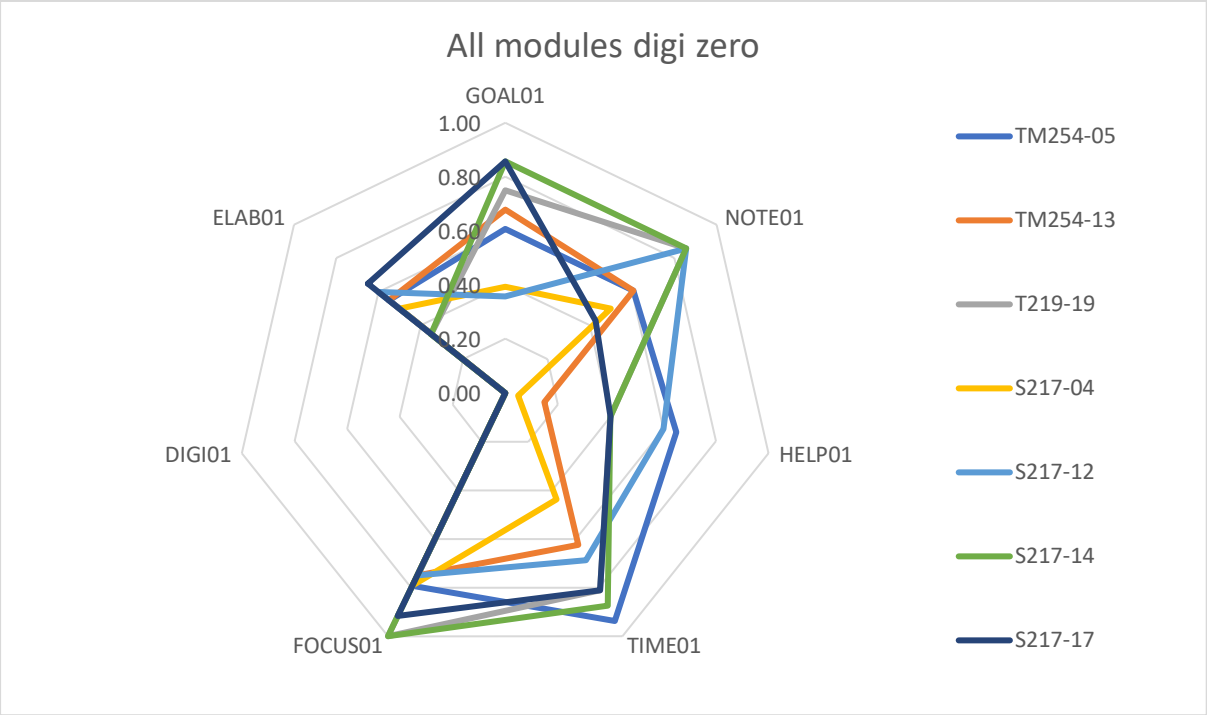
Boundaries for low, medium, high were chosen by inspection of radar diagrams, based upon typical patterns observed. These are arbitrary values, so the analysis could be repeated using different category boundaries.

low <0.2
0.2 < not low
0.2 < med < 0.7
0.7 < high

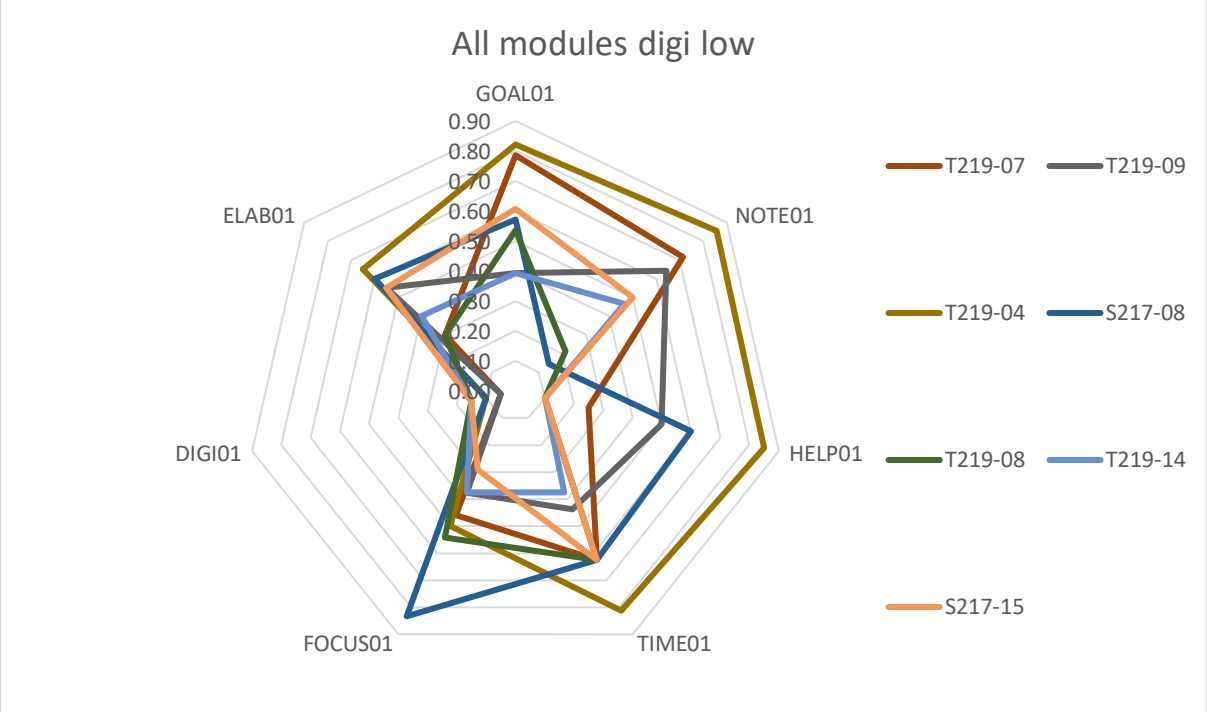
4.2 All 2020 survey modules split by digi value (zero, low, medium, high)

With this variability around DIGI identified, we can inspect the data on the R-Profiles by pivoting responses against DIGI as the main factor. This gives rise to the different groups shown in R-Profiles 13-16.

R-Profile 13



R-Profile 14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T219-07
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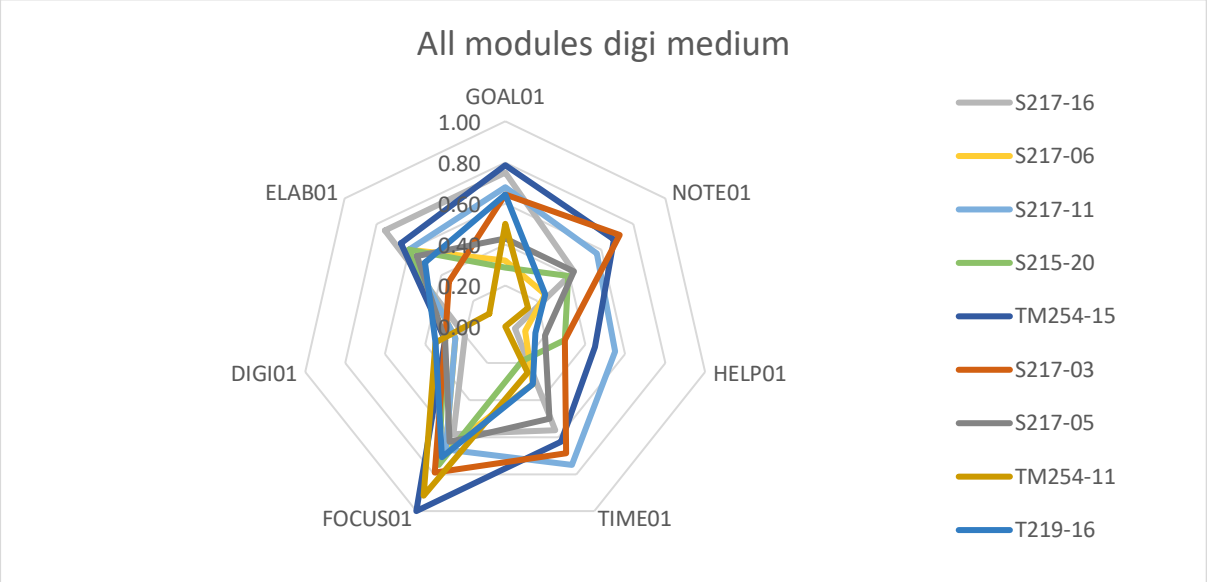
T219-04
S217-08
T219-08
T219-14
S217-15

R-Profile 15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S217-16
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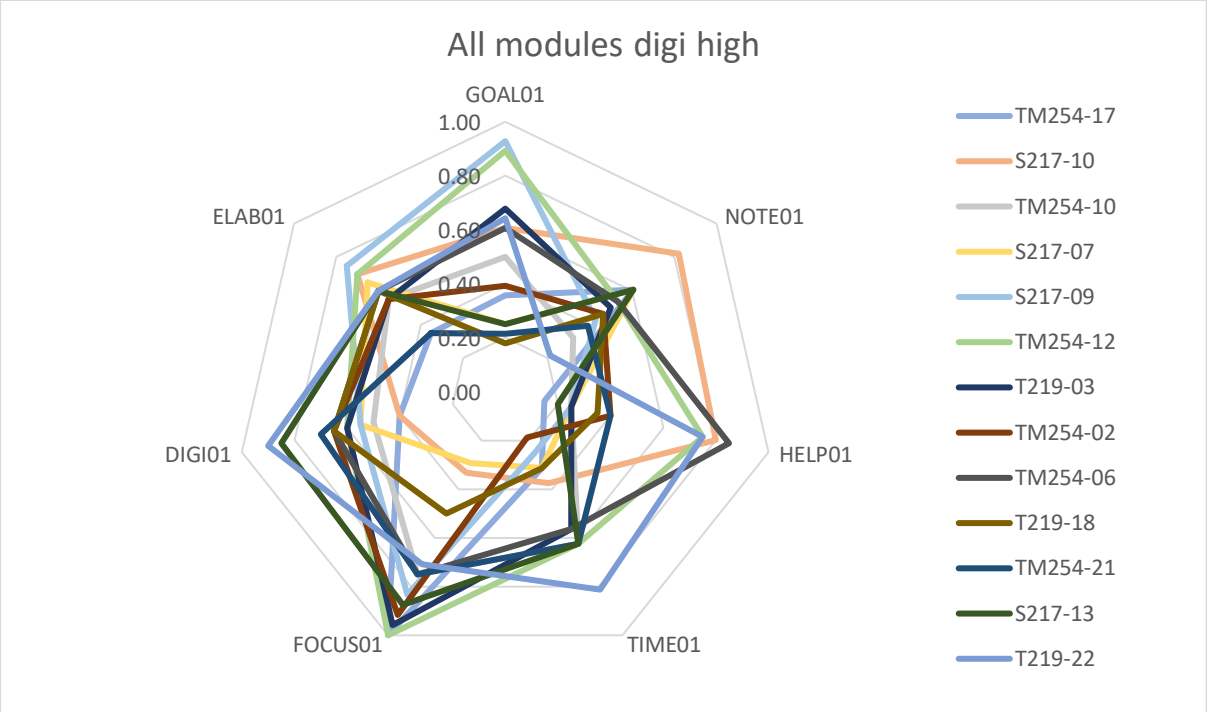
TM254-15
S217-03
S217-05
TM254-11
T219-16

R-Profile 16



2020 survey modules grouped by module code and split by digi value (zero, low, medium, high)

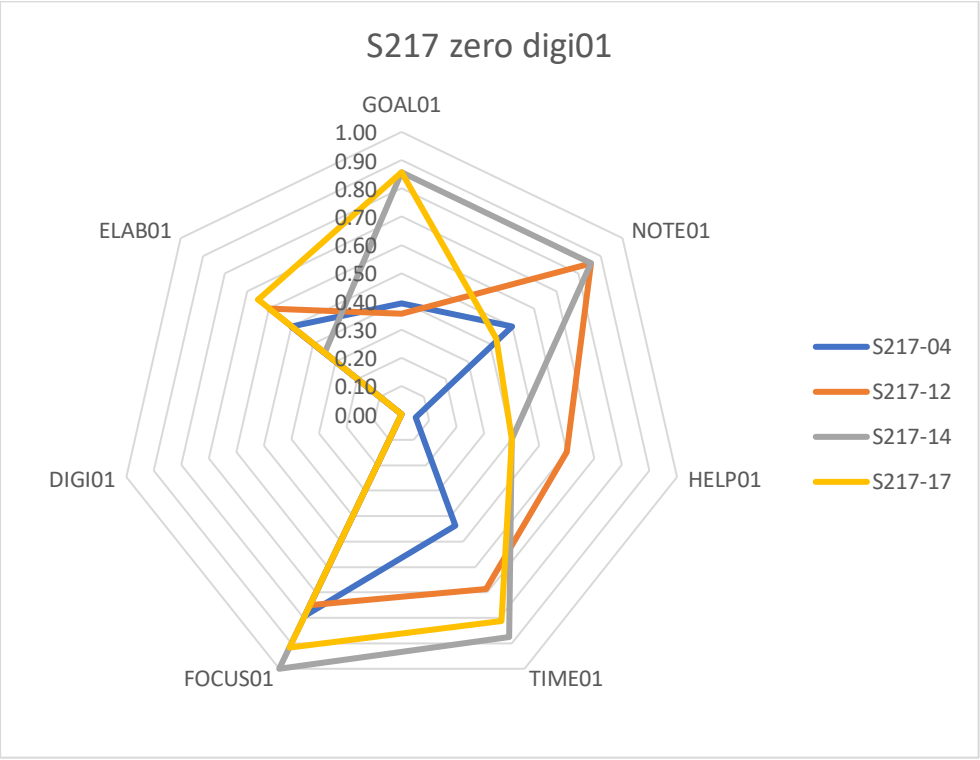
After the data was pivoted around DIGI levels, the student responses were grouped against their original module codes. This demonstrated the differences in the student experience, given they were intended by the OU to have a consistent, designed learning experience.

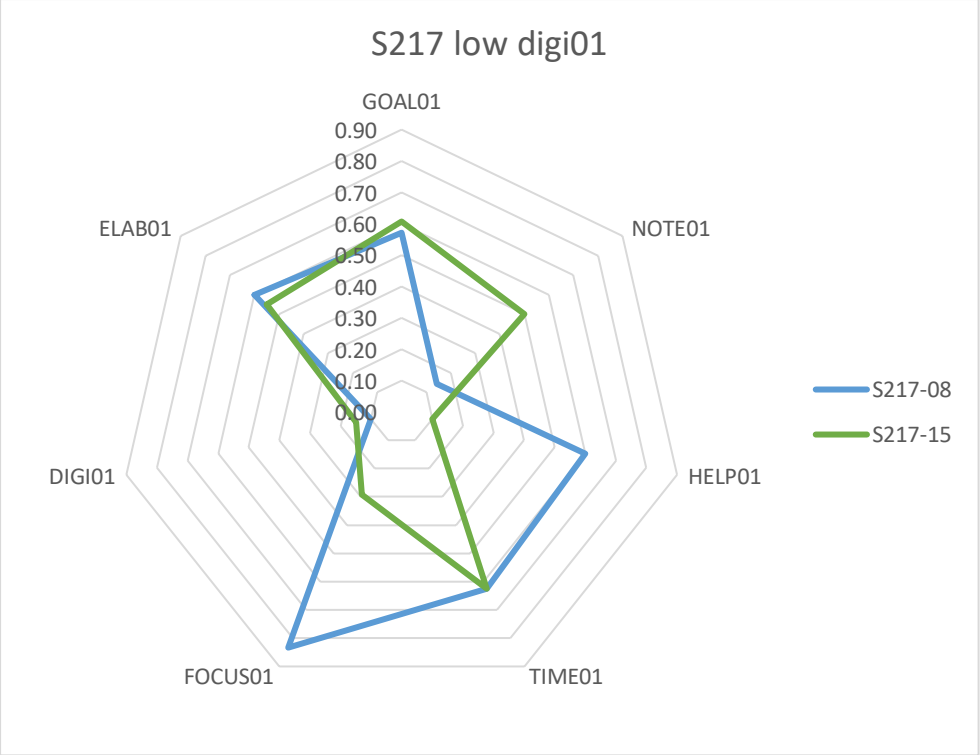
In order to understand the factors that influence the behaviours of students, interviews were conducted with some of the participants, and an analysis of the learning design activity types present in the modules was conducted against learning behaviours, in order to discern patterns of influence.

Crucially, in trying to answer the question of whether learning behaviours have an impact on student outcomes, the survey did not generate enough responses to be able to answer this question with confidence. However, the development of R-Profiles as an approach for examining the data gave the research team the opportunity to revisit the dataset compiled in the Learning Behaviours of OU

Students research project (Ellis et al, 2018), and using those students' outcomes data, we were able to answer this question more fully (see Section XX)

S217 R-Profiles split by digi (zero, low, medium, high)

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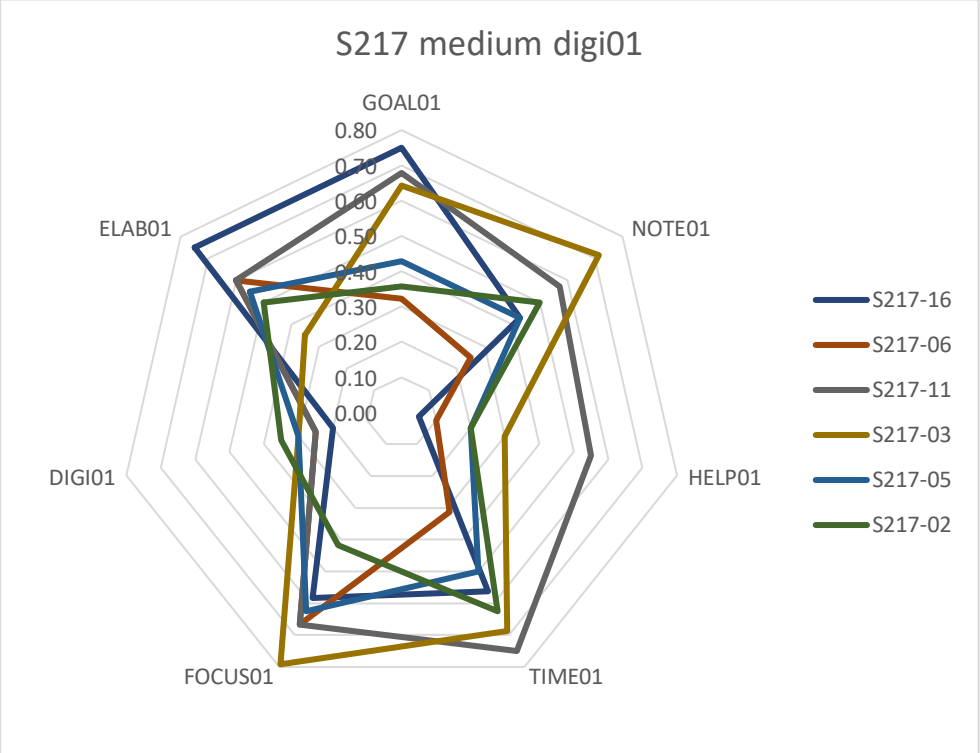
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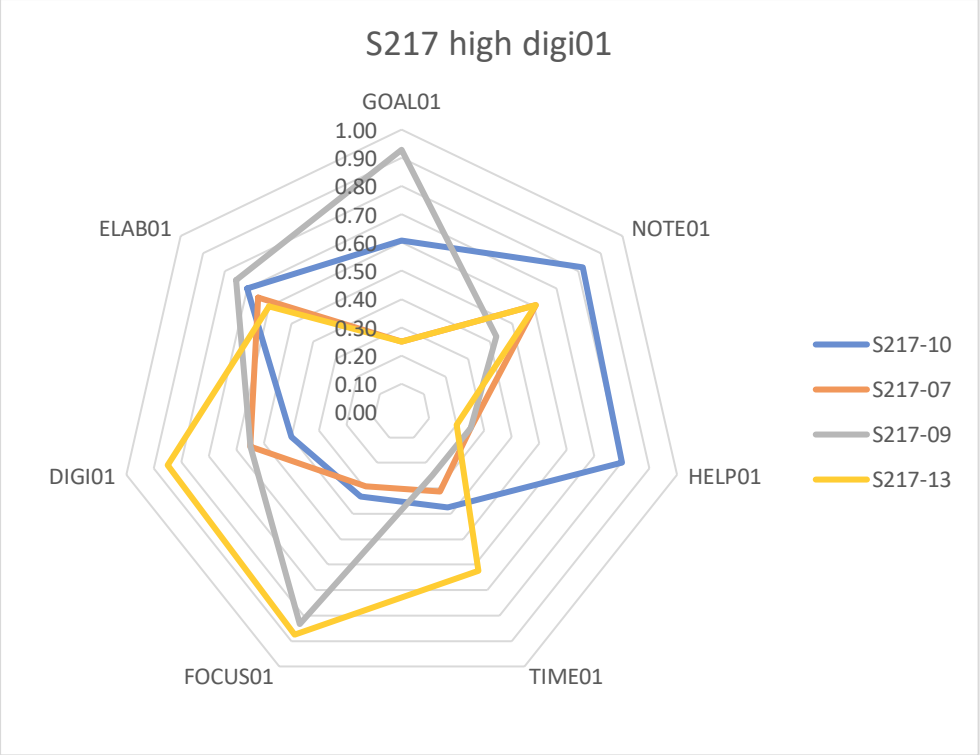
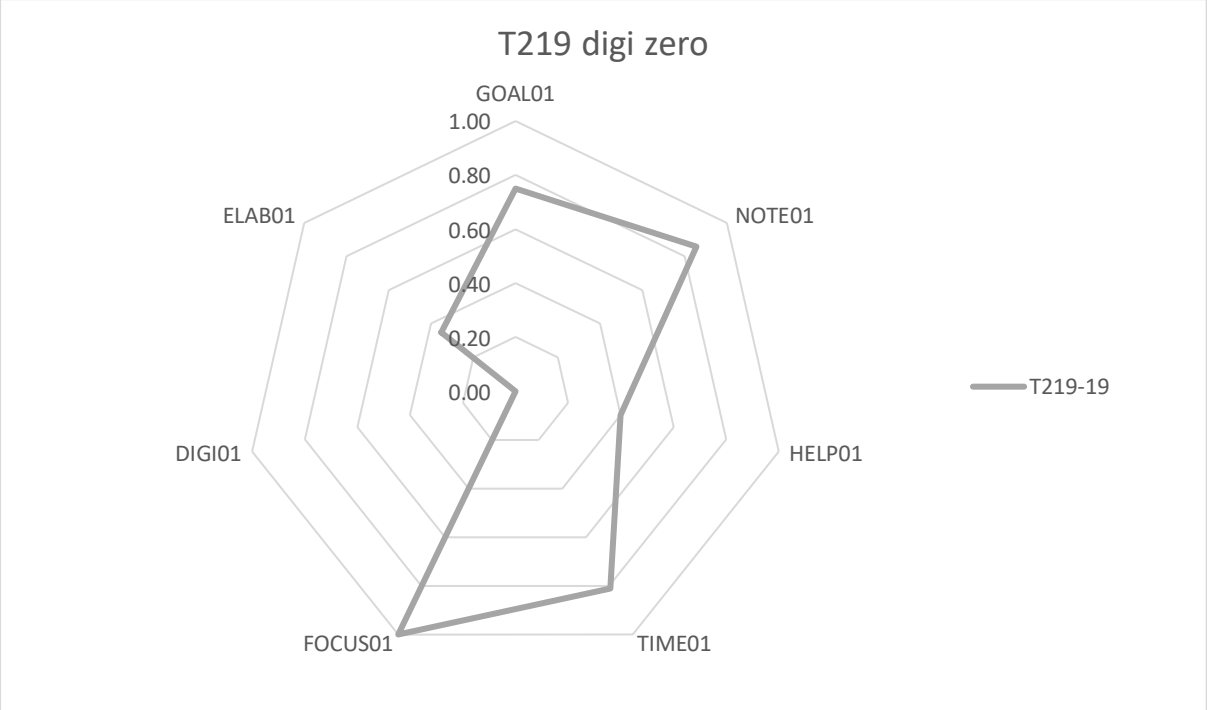
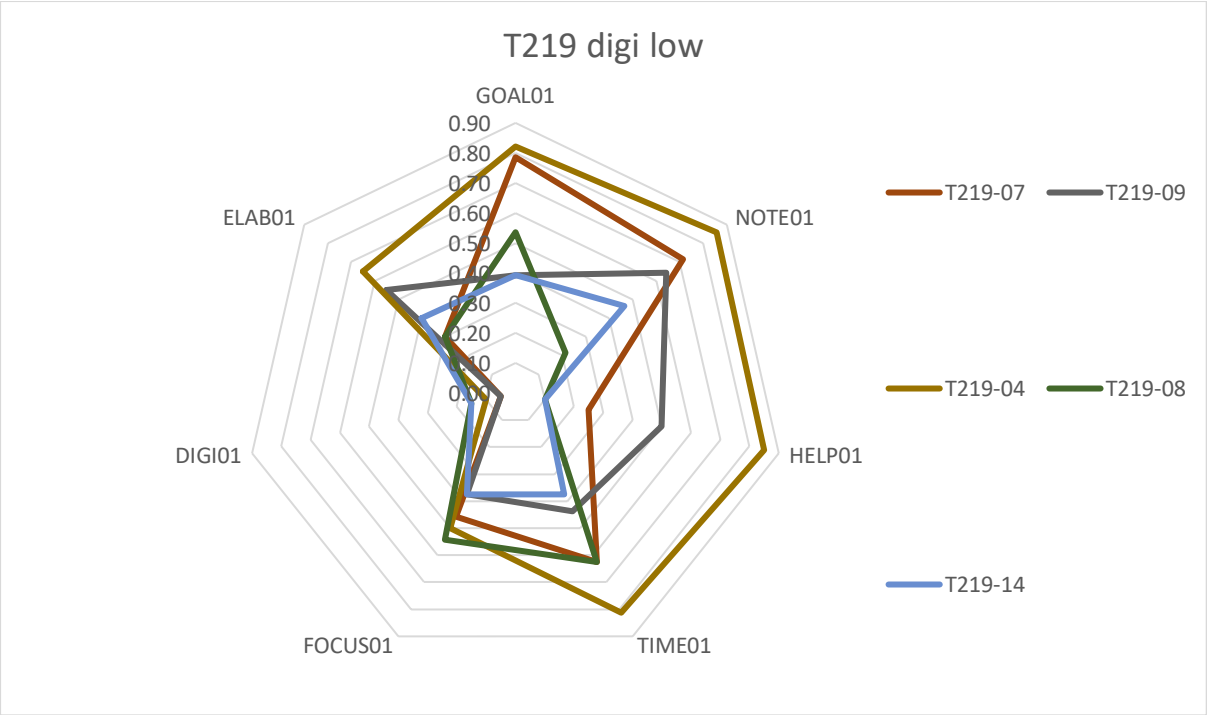


T219 R-profiles split by digi (zero, low medium, high)

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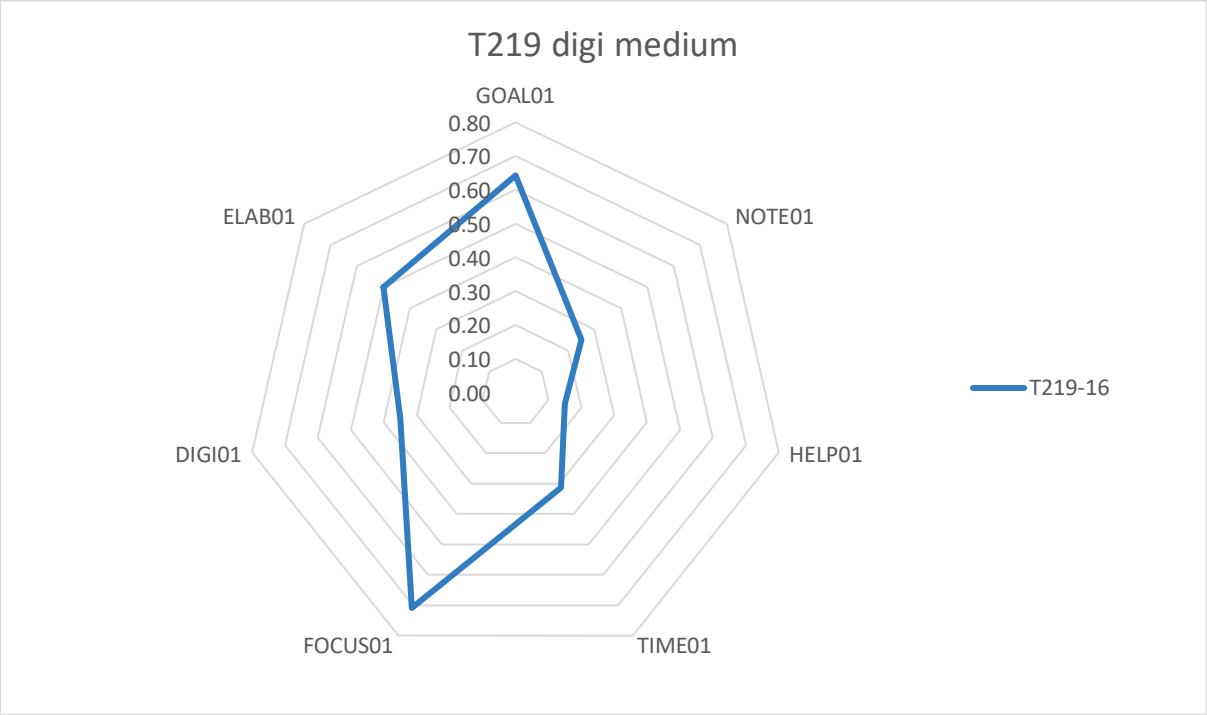
T219-14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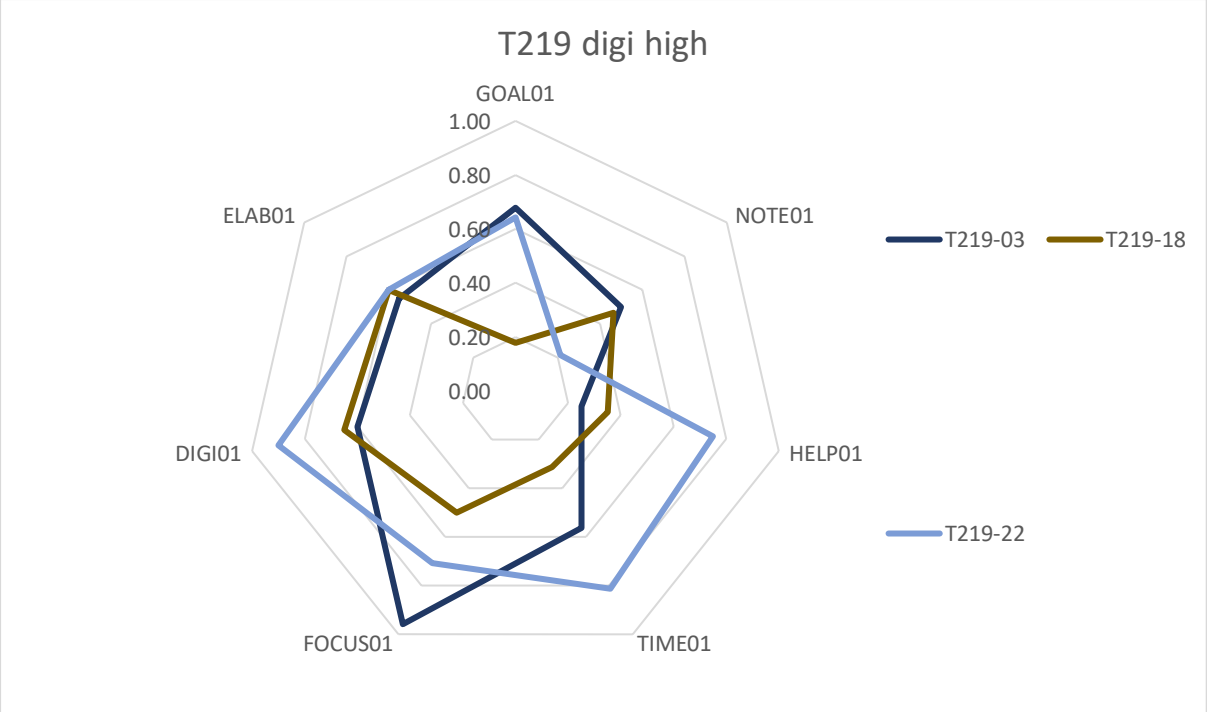
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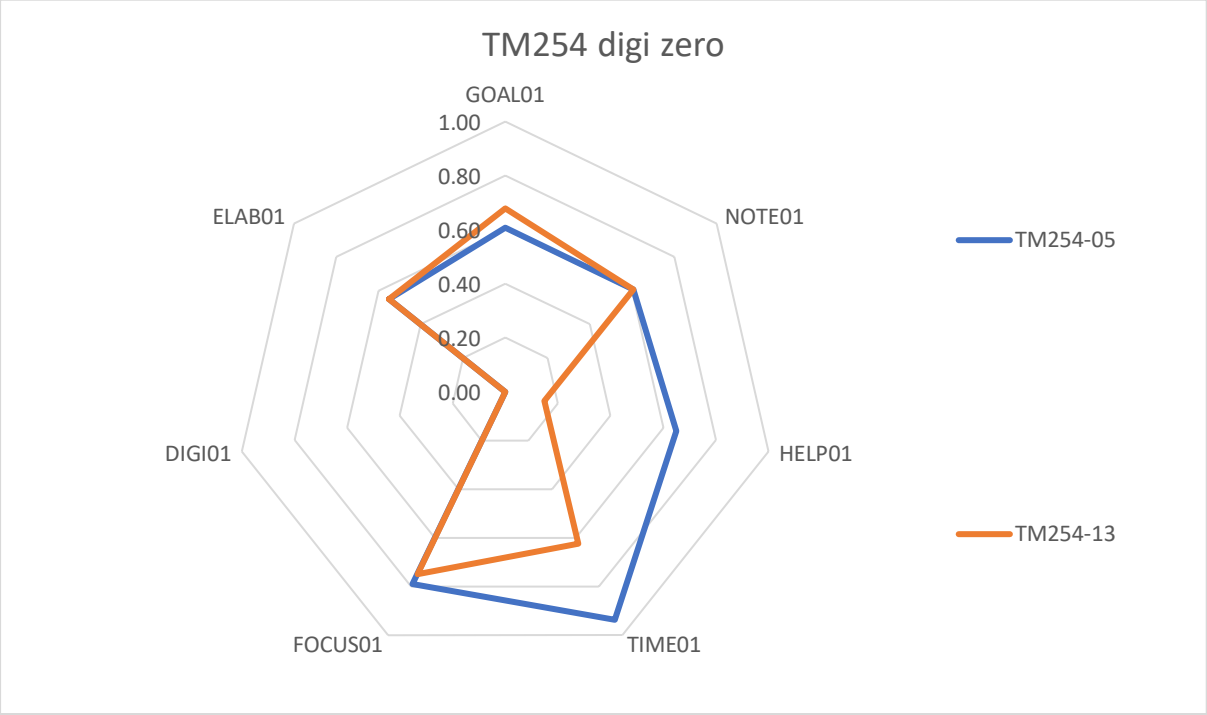
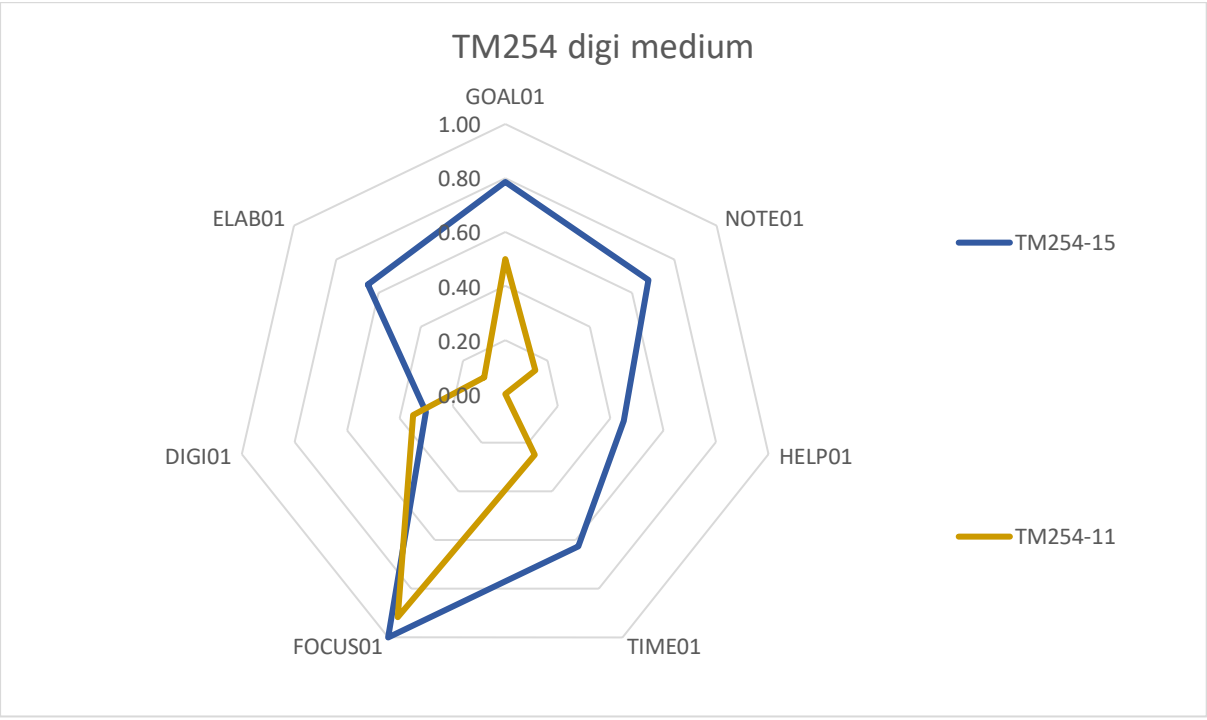
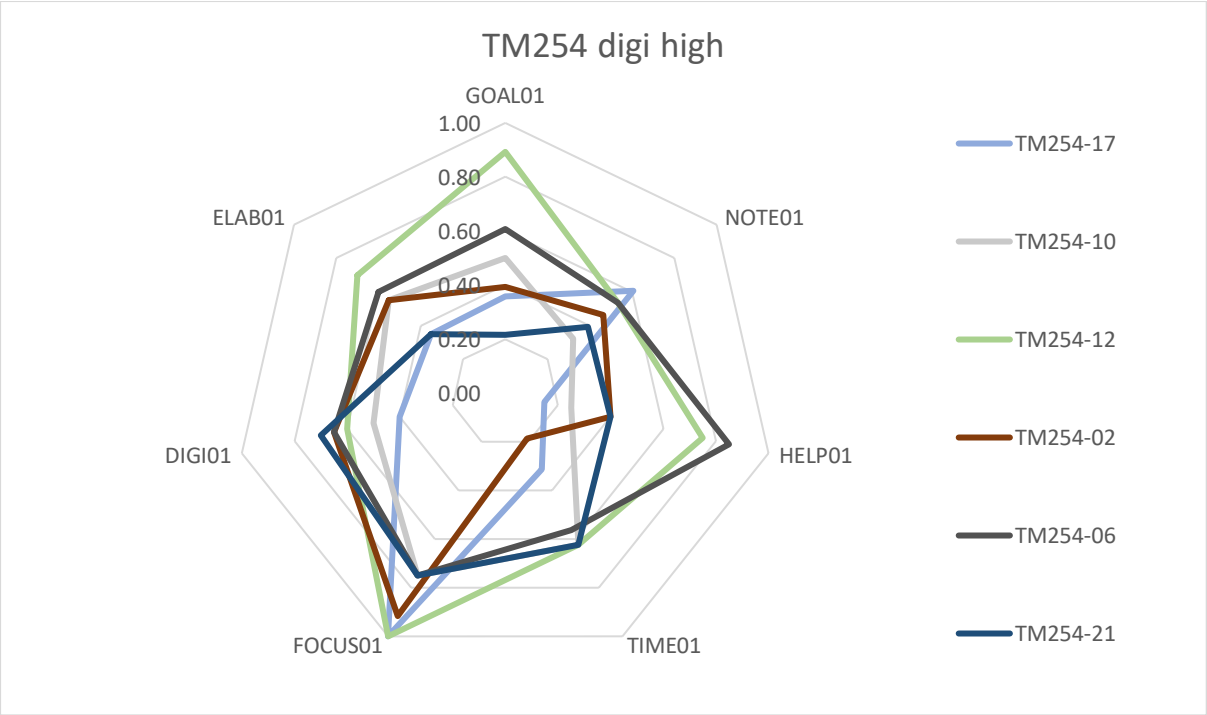
DIGI01
ELAB01
T219-03
T219-18
T219-22

TM254 R-Profiles split by digi (zero, low medium, high)

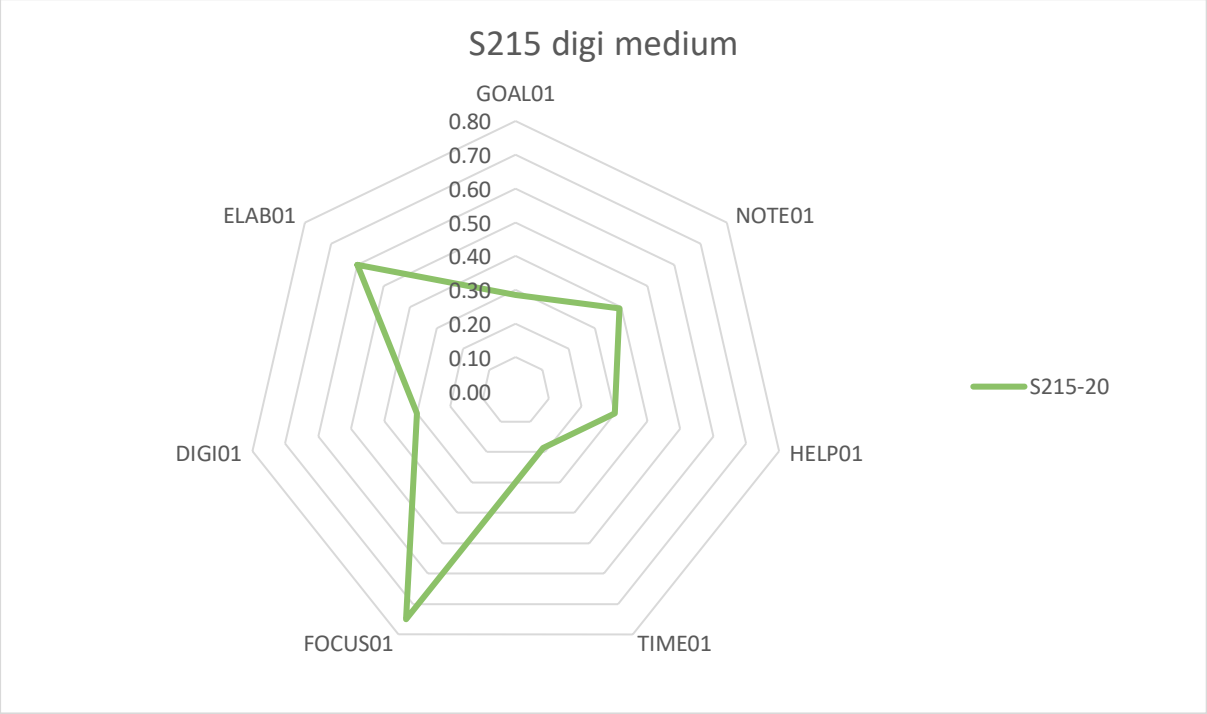


There are no TM254 responses with low digi





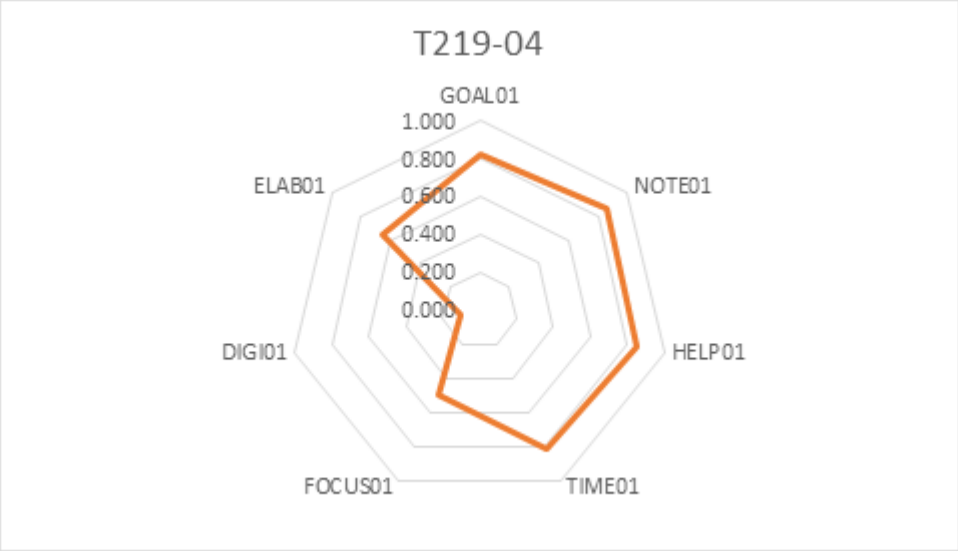
S215 R-Profile



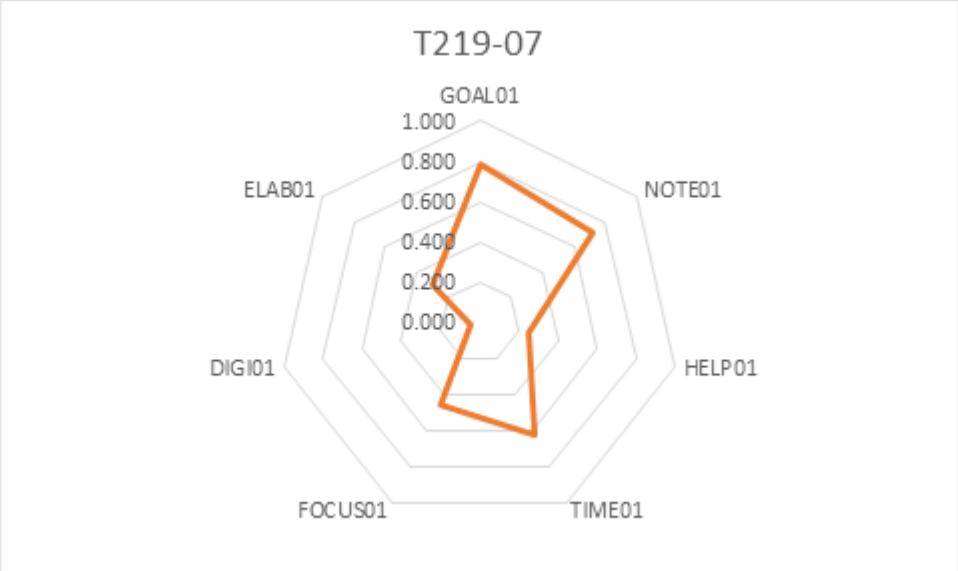
Interviews

Of the 37 students who responded to the 'Learning Behaviours of STEM students' survey, 27 volunteered to be interviewed. Six students were interviewed, with four interview recordings and transcriptions being suitable for analysis - two students each from T219 and S215 respectively. The low number of interviews provides a relatively narrow cross-section of views, and self-selection bias is to be expected, but valuable insights can nevertheless be gleaned from the data.

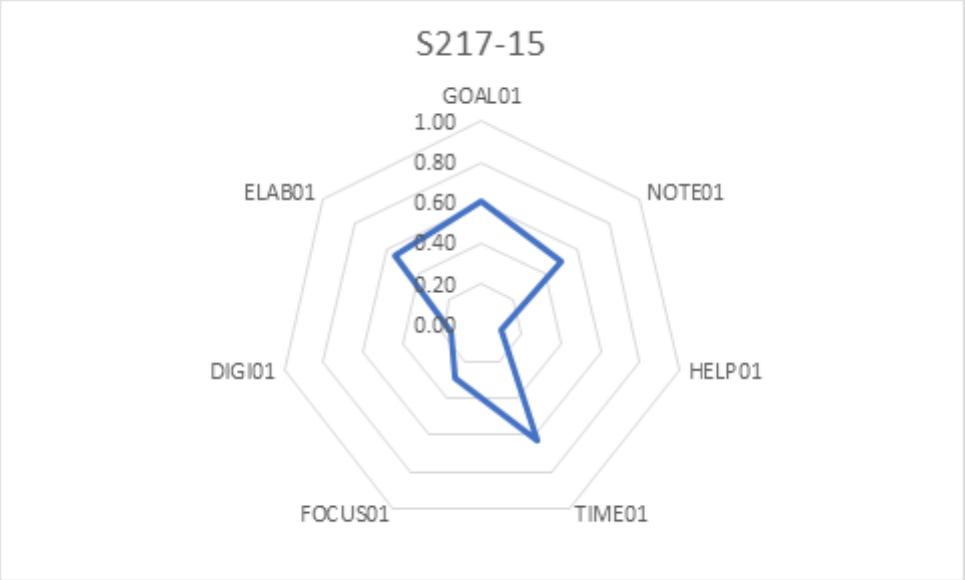
R-Profile of Participant T219-04



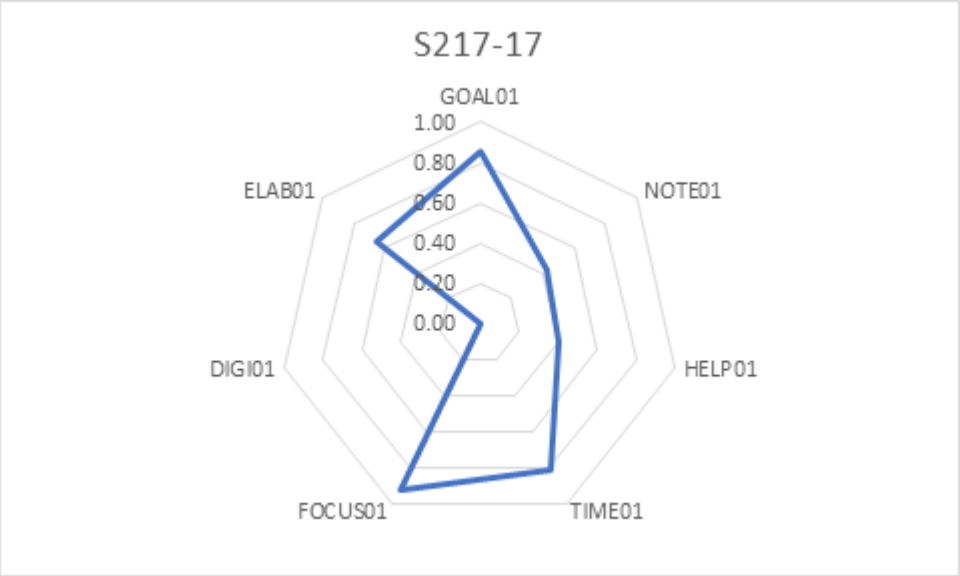
R-Profile of Participant T219-07



R-Profile of Participant S217-15



R-Profile of Participant S217-17



The students completed a 10-minute online experience sampling activity, to act as a short diary study and as an aide memoire when they took part in the interview. The 10-minute activity asked the student to describe a specific learning moment, and to share with the researcher either a photo or voice note that represented this.

Their responses and artefacts were retained and drawn on during their interview. A series of semi-structured questions were asked, after which they were shown their own R-profile (described to them as a 'behaviour wheel') based on their survey responses. The learning behaviours were explained to them, and their own aggregate levels were described as 'Very low', 'Quite low', 'Medium', 'Quite high' or 'Very high'. Students were assured during the interview that these descriptions did not reflect the scales used on the survey, but rather acted as a measure of intensity in terms of their agreement with the statements and a general level of the behaviour.

Interview analysis

A combination of deductive and inductive approaches was used to analyse the interviews. After a first read-through, nodes were created in NVivo for themes identified. All four interviews were then coded while simultaneously refining the node structure through an iterative process. A structure of nodes was then created in which the learning behaviour attribute was nested under its corresponding learning behaviour. All four interviews were coded according to those nodes as well as the identified themes.

References which seemed to code learning behaviours but not to any specific learning attribute were coded under 'keyword-[learning behaviour]'. Learning behaviour attributes which did not have any references coded to them were removed. During the coding process, it became apparent that some themes arising from inductive analysis should be nested under learning behaviours, so the node structure was further refined to incorporate this.

Finally, nodes were created for each learning design activity types, and coding was completed for those nodes so that early intersections between activities and learning behaviours could be identified.

Interview results

The final node structure is displayed in Table 4, alongside the number of references for each node and the number of files (of 4 total interviews) in which references appeared. Nodes created through deductive process appear in bold.

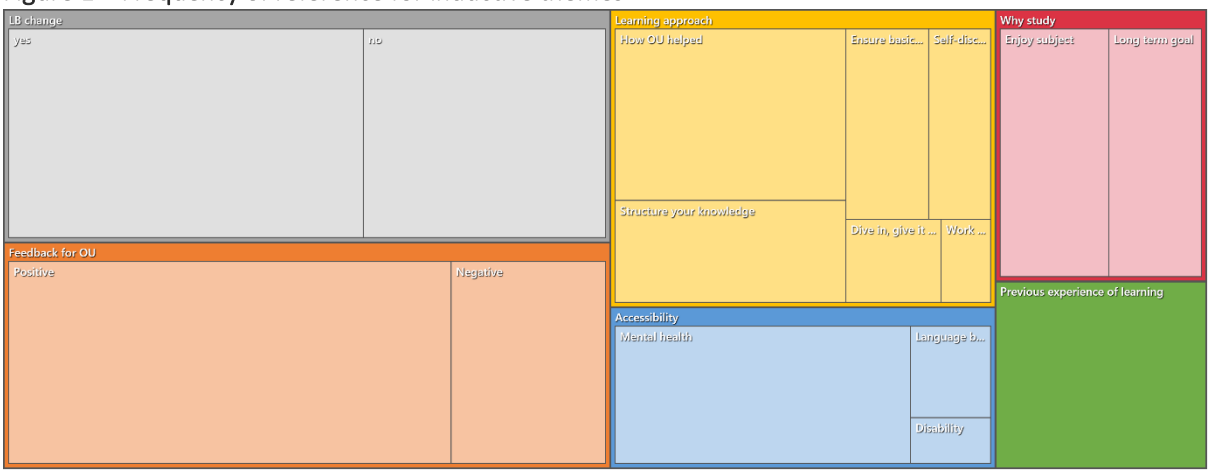
Table 4 - Node structure and frequency

Node		References	Files
Accessibility		14	3
	Disability	1	1
	Language barrier	2	1
	Mental health	11	3
Previous experience of learning		9	3
Feedback for OU		31	4
	Negative	8	3
	Positive	23	3
Reason for study		13	4
	Enjoyment of subject	7	4
	Long term goal	6	2
Learning approach		25	4
	Ensure basics are secure	4	2
	Dive in, give it a go	2	2
	How OU helped	10	4
	Self-discipline	3	1
	Work slowly	1	1
	Structure your knowledge	6	2
Change in learning behaviour		32	4
	Change	19	2
	No change	13	2
LB - DIGI		22	4
	Digi notes	2	2
	Dislike digital	5	1
	Forums etc	5	2
	Non-OU	1	1
	OU-provided	9	4
LB - ELAB		25	4
	Apply exp	5	2
	Beyond OU	4	2
	Combine info	3	3
	Relate new to old	10	3
	Deeper learning	3	1
LB - FOCUS		13	4
	Avoid online	1	1
	Avoid people	1	1
	Concentrate	4	4
	Keyword - focus	5	4
	Mainly OU	2	2
LB - GOAL		24	4
	Keyword goal	2	1
	Personal standds	7	4
	Plan assess	8	3
	Short long goals	3	2
	Time goals	4	3
LB - HELP		14	4
	Askhelp	3	2
	Askonline	7	3
	Don't need help	2	2
	Preferalone	2	1
LB - NOTE		27	3
	Handwrite notes	9	3
	Keyword - notes	4	2
	Note assess	4	2
	Note to return	4	2
	Read note paper	2	1
	Re-write	2	2
	Store physical	2	1
LB - TIME		38	4
	Keep up	11	4
	Keyword - time	4	2
	No time review	3	2
	Other activities	13	4
Learning Activities		102	4
	Assessment	29	4
	Assimilative	27	4
	Communicative	7	3
	Finding and Handling Info	15	4
	Practice	11	4
	Productive	13	3

Inductive themes

Of themes which emerged inductively (see Figure 1), the most frequently discussed was that of change in learning behaviours, or the absence of such change. This concept was referenced 32 times. NVivo's built-in word-frequency analysis revealed that 'change' (or some variant or synonym thereof) was the most frequently-occurring word in the text, appearing 952 times, although many of the words determined by NVivo to be variants of 'change' did not appear to be meaningfully related to the concept (for example 'think' had the highest frequency of the list). A keyword search based on a meaningful subset of the list[1] revealed only 57 hits. NVivo's automated processes are useful only in very limited circumstances and were not used for further analysis of these interviews.

Figure 1 – Frequency of reference for inductive themes



As several of the interview questions were focused on the idea of change, it is not surprising that it was frequently referenced. More surprising was the frequency (N=13) with which students chose to point out how much they enjoyed their subject and what they hoped to achieve by studying it (e.g. to help with their business or to obtain a higher qualification or both).

Participant S215-17: "*But this will help me to improve my English, this will help me to communicate science to the public and this will help me also for my business because I will be able to explain better, create a presentation, and explain better to the people that why they should use our laboratory and not someone else's.*"

Participant S215-15: "*I'm hoping to, after finishing this bachelor's, hoping to study something in the field of astrophysics."*

Participant S215-17*: "I want to do my doctorate with the OU, well, because I'm interested and because I am pretty sure that this will be useful for development of our laboratory, right, because even when you are advertising something, right, we can say that, well, there are some PhD students work here and things like that. It gives some weight to the laboratory."*

[1] adapt OR become OR better OR change OR changed OR develop OR development OR difference OR improve OR increase OR refine OR variety OR vary OR varying

In fact, the interviews were quite positive in sentiment overall (see Figure 2), and students were particularly positive about the OU, frequently talking about ways in which the materials or structure of the course had helped them. The OU was provided with positive feedback 23 times, in comparison to the eight pieces of negative feedback. However, students who agree to be interviewed may be more likely to be those who feel positively towards the OU and wish to help with research.

Examples of positive feedback focused mainly on how the structure of the course helped to scaffold the learning (see 'Learning approach'), and how the way in which the course was presented helped suggest realistic goals for time-management and prevent procrastination.

Participant S215-15: "*I think all of the assignments really helped because that way you're sort of forced to, you know, sit down and go through that course material*."

A student who had studied with the OU many years before mentioned how much the website had improved.

Participant S215-17: "*More entertaining, you can get like more information. Easier to use, right, and also we have like virtual laboratories and things like that and I did enjoy."*

More general comments complimented the high quality of the materials and the accessible way in which they were written.

Participant S215-17: *"And to your books, written materials, is always of high standard, as it's always been, right. […] But your books are written in a very easy way and it's not hard to understand."*

Participant S215-15: *"I think it was designed in a way that keeps you interested and that doesn't overwhelm you […] the study material also that the OU provides I find is extremely helpful but it doesn't overwhelm the student, you know. So, I think it's a really great balance."*

One student said they would continue to use the module material even after the module was over.

Participant S215-15: "*I'm pretty sure that I will come back to these textbooks even in the next stage because there are times when you just need to go back to the basics or take one step back and try to understand something in order to understand a more complex concept."*

However, not all feedback was positive. One topic of S217 was criticised by a student as needing revision.

Participant S215-17: "*Module ten, electric currents, to be honest with you I would revise it. I understood what was written there but when I got to my assignments and to the questions at the end of the unit, right, I was not able to solve any of that. So, I had to go to the internet and I had to get the information, right, and learn it. Because the knowledge represented in the module not enough to solve the problems at the end of the module, to then solve the problems given in the assignment. [...] It does not give you the necessary knowledge and necessary information to be able to understand the aspect of physics it covers."*

Other students complained that there was too much reading.

Participant T219-04: "*This stands out for me in T219 how throughout, you know, you go throughout the online module and learning and then there was so much 'Oh, now you've got to go and read this excerpt' and it was a lot of reading. [...] We're in a What's App group and lot of people sounded like they were despairing. Or actually a lot of people were not reading it at all. Because it was too much. [...] Yeah, and, you know, people really are saying on the What's App group 'I'm definitely not doing this again' you know, the next one up in stage three."*

The amount of reading also made revision difficult.

Participant T219-04: "*When it comes to the assessments it's good to go over the whole block again and, of course, doing that for something that's so, you know, reading intensive, is hard, you know, timewise."*

However, it was pointed out that in Block Three when "*they actually wrote whether it was essential reading or whether it was preferred reading"*, this "*without a doubt*" helped with time management.

Two students stated that when they didn't know how to do an activity they liked to "*give it a go"* nevertheless.

Participant S215-17: "*I'm try and just solve it by looking at it without using any calculators or any paperwork, you know, like I'm just, head on style, right I'm going to smash it now.*"

While other approaches were quite the opposite.

Participant S215-17: "*I was reading material slowly. I could not read it fast. And some of the sentences I had to translate with a dictionary to understand the meaning of that. And I believe that this helped the knowledge to sink in and this helped me to learn material better than if I could speak English fluent I would be probably just skipping through the lines".*

Figure 1 - Sentiment across all themes

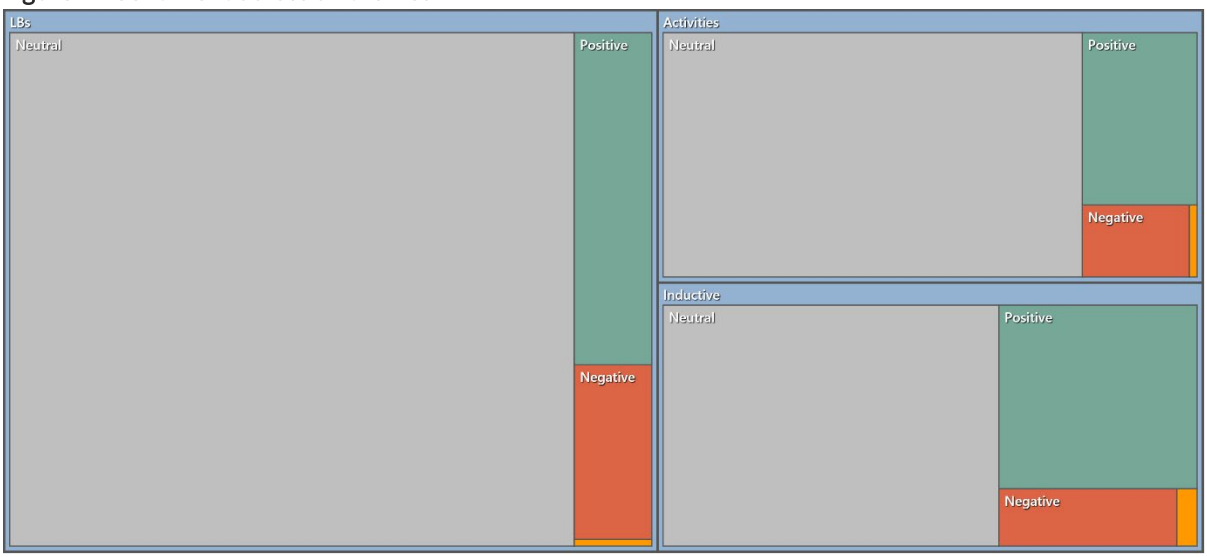
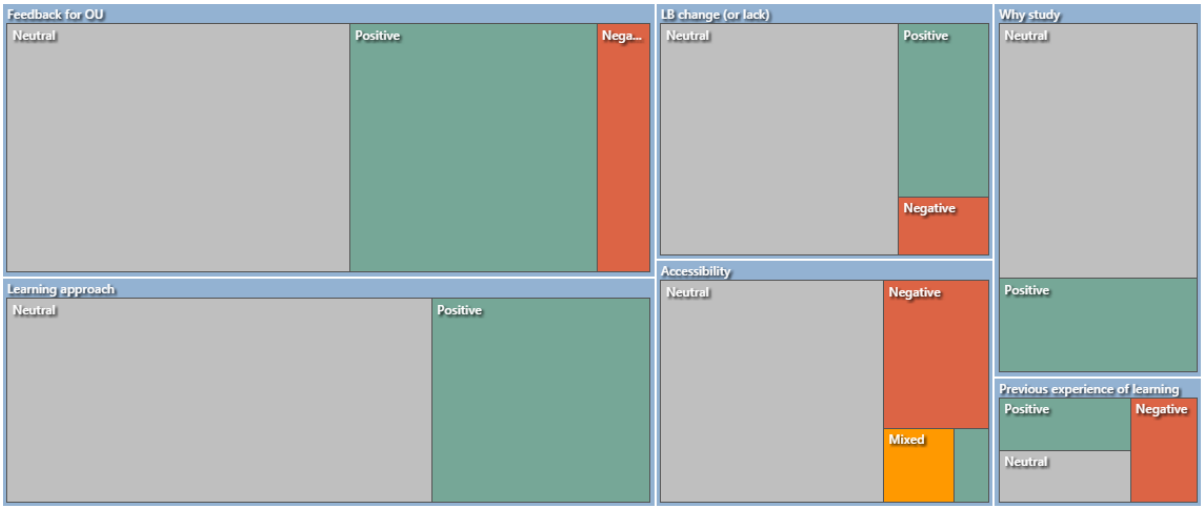


Figure 2 - Sentiment across inductive themes



The student who did not speak fluent English had found that this accessibility issue actually improved their learning, but in general issues surrounding accessibility were understandably less positive (see Figure 3).

One student had a physical difficulty.

Participant T219-04: "*For me it's a bit too much because my eyes aren't great, in fact I was going to contact student help to see if I could get some things in audio*."

But most issues were around mental health.

Participant S215-15: "*There just seemed to be so much going on and there's just so much that takes up your mind space"*

Participants T219-04 "I wasn't taking the screen break seriously. I'm going to do that more. […] I just got a bit stressed. […] I was devastated, [...] because, you know, it's important".

Students were quite self-critical on occasion.

Participant S215-17: "*But I'm always wrong and I always do the same thing over again. Yeah, I define stupidity as like doing the same thing again and again."*

Participant T219-04: "And I didn't know that either, so it just took ages".

One student described themself as "*not <u>completely</u> rubbish!"* (Participant T219-04), implying that they thought they were at least partially rubbish, saying "*I'm a little bit rubbish at getting the references correct*". The student seemed to demonstrate very high personal standards: "*And then I ended up writing a naughty little paragraph justifying my appalling referencing. But it obviously wasn't as bad as I thought because I got 93%.*"

Some of the stress and high standards may have been a result of previous learning experiences. Participant S215-15 said:

"I'm from India so in India, as in many places across the world, it's highly competitive and there's so much, I think, emphasis on your grades and your entrance exam scores and because even a 98 is not good enough. So, there is too much emphasis, on learning something without necessarily understanding why that's important, or how you're going to apply the concept."

But this student went on to explain how much they appreciate the OU's contrasting approach: "*The emphasis is on understanding the concepts and not just memorising, you know, a formula and memorising a graph just to be able to put that in an assignment or in an exam [...] all of the background on that and understanding the whys of it was what really stood out for me when I came to studying this module with the OU."*

Participant S215-17 had a very contrasting previous learning experience, having initially begun learning with the OU while in prison: "*When I started with the OU, I was serving my prison sentence [...] So, it was eight-year sentence and actually OU changed my life because I went from being a criminal to a law-abiding citizen."*

Students chose to discuss their own learning approach mainly in terms of how the OU had helped them (10 of the 26 references). This may reflect a selection bias, so inferences should be drawn with care, but the message was undoubtedly positive (see Figure 3). One aspect which was frequently praised was how the OU helped to structure learning.

Participant T219-07: "*The most blatant one is just the, especially at the beginning, of them teaching all the different diagramming techniques and then, as far as I can remember, actually explicitly making us use it to learn the material itself and then, you know, giving us chances to do that over and over. And then afterwards, as we progressed, gave us obviously more freedom to then apply it how we saw fit and more so than that, choose which diagrams we felt represented the situation the best. And* I *think it was that experience and freedom with what they'd taught us the most helpful".*

Students found it helpful to see everything laid out ahead of time as a scaffold on which to build their knowledge.

Participant T219-07: "*Off the top of my head now, to pinpoint sort of a bit of a eureka moment, I remember during one of the first diagramming exercises, I can't remember what, it may have been a multiple cause diagram, and just having it all laid out in front of me […] and it was, I can't remember the specific topic, but I was struggling with understanding it and once I had it out in front of me and I could see everything [...] everything started to make quite a lot of sense to me ".*

An important aspect was the way the module started with the basics and built on them.

Participant S215-17: "*I like to do things by small steps. It works for me, because … once I understand the first step then I can make another step."*

Participant S215-15: *"if you just look at the way the chapters and the units are laid out, right, so starting with the most basic and the kind of thing that you might have seen in grade seven or grade eight or grade nine, going to, it's sort of each unit I think complements the next. And I think the way that the*

units sort of progressed, you know, from one to twenty five, that really, that was, I thought it was laid out really well. Because, you know, it gets progressively more complex and more interesting and you have to apply yourself more and more. And that's really helpful because that way you don't feel intimidated, yeah, and you don't feel nervous about it from, you know, just when you open and see unit one is something that might be a little more challenging. So, I think that way it was laid out really well, that really helped. And, yeah, so each unit, most times, each unit informed the next."

One student found it helpful to have the learning process explained for them.

Participant T219-07: *"I think the main thing that I got was, and I may not have actually said it explicitly in that, is the learning cycle of T219. And, like I was saying about just being able to reflect and also through that reflection connecting how all my learning fit together."*

The skills learned from the module in terms of structuring knowledge were seen as applying outside the module as well.

Participant T219-07: "*Definitely going forward it's something that I will continue to apply. And even with, like, job applications and things, I mean, I've got somewhere around here just like a series of different diagrams basically helping me to once again consolidate my thoughts on how to best answer the questions."*

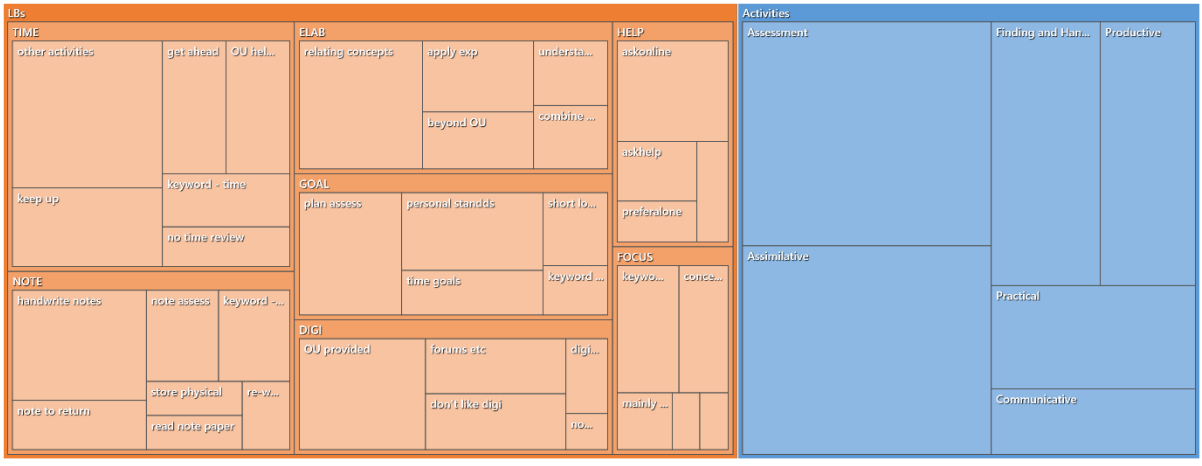
Deductive themes

Figure 4 shows the frequency with which deductive themes were referenced. 'Assessment' type learning activities were mentioned 29 times, for example, and 'Assimilative' learning was mentioned 27 times. As interview questions concerned mainly learning approaches rather than assessment activities, the fact that students chose to focus on assessment activities to such a degree is significant.

Many students referred to the usefulness of assessment activities in motivating them to get work done, and in structuring their learning.

Participant S215-15: *"The submission of assignments basically brings you back to what chapters you need to study and that's how you work back from your submission date many times.*"

Figure 3 - Comparative Frequency of Learning Activities and Learning Behaviours



Digital-preferred

Under DIGI, the only 'official' learning attribute (i.e. measured by the survey) which was referenced was 'digi notes', and this was only mentioned twice across all interviews. However, digital preferences (or lack thereof) were discussed more frequently. It should be noted that all four students happened to have low DIGI scores (3 were 'very low', 1 was 'quite low', see Table 2) so it is not surprising that they did not have a lot to say on this topic.

Table 5 shows the number of references for each learning behaviour plotted against each student's aggregate level of that learning behaviour as measured by the survey and described to the student using their individual R-Profile.

The numbers for DIGI seem to be higher for students who have the lowest DIGI scores, which is likely to be due to the number of times students expressed their disinclination for this type of working, for example "*Oh yeah, I don't do that much, no*.", or "*outside of the OU materials I didn't really use anything else*". One participant gave many reasons for their active dislike of digital working.

Participant S215-17: "*Maybe I'm not modern enough, I don't know, maybe, but ... all this digital, right, applications that designed to help you and things like that, basically they tell you what to do and … when you rely on other things, right, ... you lose your own ability to do that. ... The way I see it, right, for example, like we had in the past we had many great scientists, right, they never had anything like that, like computers or anything else, right. They did by focus and by determination. From little things they had, they had really nothing, pen and a pencil. So, and just their mind. And they got much further than we can get now*."

Every participant mentioned the OU-provided digital content, which included the VLE, videos, audio content, virtual experiments and hide/reveal online questions. Even though the four participants had low DIGI scores, they appreciated the OU-provided digital content.

Participant S215-15: *"The material that's online, right, you have virtual experiments that you can carry out, and observations you can make, or there's a lot of this extra trivia and snippets of, you know, extra information, that makes it extremely interesting. ... And I think that helps fill some of these little gaps that pop up every now and then."*

Participant S215-15: "It's important to carry out these virtual experiments because it really helps you get an understanding and helps you visualise it in a different way. Because here is the difference between the textbook and doing the material online, right. There's some things you can't do with just a book so that's why it becomes important to be able to access that material online and do some of those experiments and things like that."

One student specified that they preferred the OU-provided digital content over other content online.

Participant S215-17: "*If you go, for example, to the internet and search some subject in the internet you get so much errors from the internet, it's not so student friendly. You have to spend hours and hours, right, to make sense of what is written there.*"

In terms of working online, most of the four appreciated the online activities.

Participant S215-15: "W*here it came to those kinds of activities I think I enjoyed doing those more online, for two reasons, one is you have like almost instant access to the answer after you've tried to figure it*

out on your own. So, I would try to do it by myself but then you can still reveal and you have the answer right there so you can see it along with the question. So, with the textbook that was a little more challenging because you'd have to like flip, you know, go all the way back to the end of the book and then kind of just look at the question again, go back look at the answer. .... So, I think these activities I enjoyed doing those on the module website."

One student used the activities as a way of making digital notes to come back to at a later stage.

Participant T219-07: "*the activity ones are the ones where you're, you know, typing out your answer? Yeah, so I would capture my thoughts on the matter at the time, especially because I often found when going through your TMA and then going reflecting back onto that material, it was actually really helpful because I could see my thoughts at the time and thinking 'oh actually, yeah, that's how I felt about it and I actually think that that is right'."*

On the other hand, one student specifically disliked the online format of the activities, preferring to answer on paper.

Participant S215-17: "*I always get wrong this types of questions ... I may get right answer on the paper when I solve it but when I input this into the system it's going to be wrong ... because I may miss like minus sign".* This student later discussed how their attitudes to digital working affected their concentration "*Just my attention, it's just my attention. ... When I see some computer problems or computer queries or question I never take it seriously. I think this is just, you know, like some trivial problems that I can smash it like that, I don't have to pay much attention, right, I can get it easy. But I'm always wrong*".

Finally, students mentioned using the OU forums to connect with other students, but mainly in the context of wishing they did this more:

Participant T219-04: *"I must get more involved in the forum"*

Participant S215-17: "[In future modules] I would share my ideas and talk more to other students or to my tutor."

Table 5 - Participants' behaviour wheel levels and number of references to each learning behaviour

Participant:		S217-15	T219-07	S217-17	T219-04
HELP	**Score**	Very low	Quite low	Quite low	Very high
	Refs	1	3	3	5
TIME	**Score**	Very high	Medium	Quite high	Very high
	Refs	7	5	11	10
GOAL	**Score**	Medium	Very high	Very high	Quite high
	Refs	7	5	5	6
ELAB	**Score**	Medium	Quite low	Quite high	Very high
	Refs	5	8	2	3
NOTE	**Score**	Medium	Very high	Medium	Very high
	Refs	3	5	0	7
DIGI	**Score**	Quite low	Very low	Very low	Very low
	Refs	5	3	7	7

FOCUS	Score	Quite low	Quite low	Very high	Medium
	Refs	3	2	3	2

Time

As shown in Table 2, students with higher TIME scores tended to discuss it more. However, what was mainly discussed was lack of time; 13 references were made to not having enough time to study because of other activities.

Participant T219-04: "*You know, with little children and stuff [...] I juggle a lot of balls."*

Participant S215-17: *"I have to combine my studies with my work and I'm working like ten, eleven hours a day. So, I've had to fit my studies into the spare time I have."*

Participant S215-15: *"I cannot, simply cannot apply myself and do this because of work and everything coming together."*

Three further references specified lack of time for revision.

Participant T219-04: "*When it comes to the assessments it's good to go over the whole block again and, of course, doing that for something that's so, you know, reading intensive, is hard, you know, timewise."*

Online activities were also skipped due to lack of time. One student said: *"If I'm perhaps, if I feel that I'm pushed for time"* they would *"be naughty and write a couple of words and then it'll let me reveal the answer. [laughing]."* (Participant T219-04)

It was reported that many other students were also skipping readings. "*We're in a WhatsApp group and lot of people are, you know, they sounded like they were despairing. Or actually a lot of people were not reading it at all. Because it was too much. And I thought 'Ooh'. I'm not a square but I mean I was devastated, not reading it because, you know, it's important."* (Participant T219-04)

One student noted that keeping up was less important in previous modules.

"*I think maybe I approached this module with a little bit, at least the stage two modules, with a little bit more discipline than the stage one modules. [...] There were times when I found myself sort of allowing things to pile up a little bit, but I was still able to finish all of my assignments on time and I think do what I needed to do. But at this module I found that I couldn't allow that to happen too much just because, you know, the materials are so much more complex and so much more vast."* (Participant S215-15)

Some students said they had found it easier to keep up previously. *"But I think maybe I had more time, maybe I had like less distractions."* (Participant S215-17)

"I needed to ask for, I think, a couple of timeline extensions. And so that was something new this time in stage two and this module. [...] I didn't feel that need, I think, in stage one at any point." (Participant S215-15)

The main strategy adopted for keeping up seemed to be to create a buffer zone by getting ahead at the beginning of the course.

Participant T219-07: *"Always start off the same with lots of ambition when it comes to getting those early starts."*

Participant S215-17: "*I started to revise for the course, I think, in June. ... So, by the time I started actually the course, by the time I received the course material, I already was confident that that at least I going to get the pass mark. […] And well it was good thing that the course material I received maybe like one month before the starting date. So, I had some extra time, yes, and, well, I used the most of it just to get in front. […] And so, by the time the course started I already submitted the first assignment so I was one month ahead."*

Students at least attempted to keep this buffer zone in place.

Participant S215-15: *"Maybe try and stay ahead a little bit."*

Participant T219-04: *"Now I'm better prepared for my TMAs. I start them earlier. I start them a lot earlier"*

But with varying success.

Participant S215-17: *"By the middle of the course I started to feel that I'm falling a little bit behind."*

Sometimes this was through the students' own fault - *"just that sometimes you procrastinate"* (Participant S215-15) - and sometimes not - *"despite some of my best efforts, yeah, I had to ask for an extension sometime in I think March or something"* (Participant S215-15) - but participants were mainly positive about their efforts to keep up with readings and assignments.

Participant S215-17: "*Just I was studying to catch up, right, and luckily I did catch up for the course and passed my exam in June."*

Participant T219-07: "Occasionally when there was a lack of time and, you know, I was getting behind [...] I was sort of not really engaging but that was the rarity."

However, these efforts to catch up may have caused other commitments to suffer: "*I was able to spend some time in the morning [...] for my studies and the rest I was catching up at work. So that's how I was catching up, at work."* (Participant S215-17)

Help-seeking

Participant T219-04 had a very high HELP score, while the other three students were very low or quite low. The number of references shown in Table 2 seem to support these scores, as did the content of their comments, for example the student with the lowest score specified that:

"*Seeking help and actually reaching out is something that I have done very little of this entire module. So, not because I don't want to, because most times I didn't feel the need to, which in a sense, really speaks to the great quality of a lot of the materials."* (Participant S215-15)

Asking for help was not seen as a negative thing. One student with a quite low HELP score said they did not ask for help unless it was needed, but "*especially when it came to the EMA actually, there were*

several times where I felt that I did need that help so I was in contact with my tutor". (Participant T219-07)

This student had enjoyed group work, "*mainly because of the fact that we could all help each other, refine each other's ideas. So, yeah, so that was great".*

Another said they preferred to work alone, even when things were difficult: "*I'm trying to find the way to reaching this target myself, right. I don't really rely much on other people. Because what I think is, right, if I do what other people tell me I don't have my personality. And the thing is when I set a target and if I manage to get there the first time myself well that gives me a little bit more confidence that I will get there for a second time too."* (Participant S215-17)

However, this student hoped to change that behaviour in the future, saying that in their next module: "*I would share my ideas and talk more to other students or to my tutor. That would help me to consolidate and that would help me probably to make sure that my understanding of this subject is correct. And I would probably do that more. It would help now to memorise and to remember. I think I should be more sociable."*

It may be that after having taken part in group work such as in the EMA of this module, students are more likely to reach out to others.

Participant T219-04 had a high HELP score, was in a WhatsApp group of students on the module and had been in frequent contact with them. However, this did not appear to be entirely a good experience: "*Oh, it takes over your life really. And actually, it's not very good because you've got all sorts of people on there and some are actually over panicking. Yeah, loads of them."*

This student said they would prefer to use the forum in future: *"I must get more involved in the forum because there's so much on the WhatsApp group, which isn't so important."* The student seemed to have found that other students had different views from their own *("they tend to mock the rich pictures and I love them. [laughing]")* but that *"it's nice when you find one or two and then you can just be friends with them, you know, proper friends".*

Elaboration (ELAB)

All learning attributes associated with ELAB were referenced during the interviews:

I try to apply my previous experience when learning.	apply exp
When I am learning, I try to relate new information to what I already know.	relate new to old
When I am learning, I combine different sources of information (for example: people, websites, printed material).	combine info
When I am learning, I look for information online beyond what is available from Open University websites.	beyond OU

In addition, Participant S215-15 talked about the importance of deeper learning, of understanding "*not just the how but why*". They had appreciated being given the background to enable this deeper understanding.

They said: "*There's so much emphasis on understanding why, you know, some scientist in some year concluded a certain thing or why it is that we have so many equations and we have so much that is taken to be that's understood as common knowledge. So, how we even got there, I think all of this, all of the background on that and understanding the whys of it was what really stood out for me."*

Students talked about how the OU materials were structured in such a way that later material built on earlier material, allowing them to relate the new material to what they had already learned "*so each unit, most times, each unit informed the next*". (Participant S215-15)

Participant T219-04 felt the materials encouraged them to relate concepts, "*really instilling in you that you've just got to look at connections and relationships when looking at a problem*", and to apply their experience: "*At first I actually just did all of them and then after rereading the text books with T219 or the resource book, I figured out that, or rather reread that they had suggested that specific diagrams be used to specific purposes, i.e., which picture is used for reflection on a specific situation and then things like multiple cause for actually modelling it out, and relearning that or reflecting on that through the EMA process was great.*"

Rather than only applying existing knowledge to new problems, one student found themself applying their new knowledge to old problems, because they had found the material "*awakes a natural curiosity I think or sometimes gives you answers to questions that you've wondered about*". (Participant S215-15)

There was relatively little tendency to go 'beyond OU' to find information, but some students had done this: *"My interest was really sparked. I mean, ever since then I've begun the process of reading books on systems thinking [...] there's a free diagramming tool online, Drawio, which I use."* (Participant T219-07)

One student mentioned doing this for a previous module. *"I bought some books from Amazon from the predecessor of 217, it was 207 I think, S207, the physical world, I bought the first two books and I started working through those books […] I had to go to the internet and I had to get the information, right, and learn it."* (Participant S215-17)

The number of times ELAB was referenced does not seem to be related to the participant's ELAB score on the R-Profile (see Table 5). This may be because the participant who scored 'quite low' was surprised by the score, and went on to talk about this, while the two who scored highly did not discuss it.

Focus

The number of references were similar for each student (see Table 5) although the content was very different for the students with lower FOCUS scores. Rather than talking about behaviours they engaged in to improve their focus, these students tended to discuss aspects beyond their control such as unavoidable distractions, or the diurnal ebb and flow of concentration levels.

"*I'm easily distracted […] You know, if you've had a bad night, I've got small children, to sit there and read all that is a struggle."* (Participant T219-04)

"There's just so much that takes up your mind space" (Participant S215-15)

"*I'm much more of an early bird than I am late. So, my concentration is far better in the morning. ... And it depends on work as well".* (Participant T219-07)

This may indicate that some students view focus as something they either have or do not have during a study session, and do not attempt to change or improve it. However, they can still change their behaviour to work around it; one student changed their note-making behaviour based on their available concentration.

"It depends on my level of concentration at the time and the focus I can muster. If I have a lot of it I would read through say a whole page, the equivalent of a tab, think about it and then write notes on it, then reread it and then carry on. If I have say, I don't know, a mediocre amount of concentration, then I will make notes as I read it." (Participant T219-07)

When asked to expand on this, Participant T219-07 continued: "*Because when I have a lot of concentration I see the benefit of trying to read, think about the material, solely concentrate on that, then write down sort of what I feel I've learned from it and the takeaways. I think it's much better for my memory of it and much better to help me distil my own thoughts on the matter. The reason why I don't do that all the time is because I can't. if I had unlimited amounts of focus and concentration that's pretty much how I'd do everything but when it comes down to, you know, say if I've been at work and I've come home and I had to study or I've already done four hours of T213, you know, there's only a finite amount of concentration in which I can use."*

The fact that all students discussed FOCUS to a fairly equal extent may indicate that all are equally aware of its importance, even if some respond differently to that awareness. One participant treated concentration as a finite resource to be used judiciously, and said that while reading they would flag concepts that would need higher concentration: "*Something that tells me that when I go back to that page or that topic this is what I need to look at or this is a thing that I tend to, you know, forget, so I need to pay extra attention."* (Participant S215-15)

And some students did take actions to help themselves focus, whether this was planning sessions for when their concentration was at its best: "*It's often early mornings, earlyish, sort of 6am starts when it comes to studying,"* or avoiding distractions as much as possible, "*I do prefer to be solely concentrated. So, having that, not having sort of scattered focus when it comes to it. So, sitting down for a few hours, all other distractions away.*" (Participant T219-07)

One student went as far as avoiding all contact with other people for days at a time: *"Isolation. I don't like distraction when I'm studying, I don't like distraction. I like to concentrate on what I'm doing. I do not pick up the phone, I don't talk to people mostly, especially when I'm from some hard aspect, something I cannot understand. There have been some problems on physics on this module I could not solve for a week and so basically I don't talk to anyone for a week, I'm just going and thinking it over and over and over and over. So, isolation helps."* (Participant S215-17)

Goal-setting

The GOAL learning attributes which appeared during these interviews were 'personal standds', 'plan assess', 'short long goals' and 'time goals'. Many comments were about how goals were set around assessment activities, partly because assignment deadlines required time-related goals ("*You work back*

from your submission date“, Participant S215-15), and partly as the assessments tended to guide the topics studied (“*You’ve got to maybe look at your TMA or whatever first, identify what you mainly should be looking out for”,* Participant T219-04*).*

Students tended to “*change my planning for specific TMAs”* (Participant T219-07), and they found that the OU tutors helped them set goals based around the assessments.

“I watched all the tutorials and I always found in T219 that they were very, very good in explaining what was expected of us in our TMAs and EMA. I often found the TMAs themselves or even the module material when it did allude specifically to the TMAs sometimes a bit vague, but [...] whenever it came to the tutorials, yeah, they always gave me a lot more insight on it, [...] I watched them over and over again and they really helped me narrow down what I needed to get done on my EMA.” (Participant T219-07)

The concept of ‘narrowing down’ what needs to be done for an assessment was also alluded to by another student in the context of not spending more time than was necessary: “*If it’s studying for an exam, or if it’s that then I’d probably skip the stuff that I haven’t previously marked and just focus on, you know, revising the concepts. Because sometimes you don’t need to revisit everything if you’ve done it once already.*” (Participant S215-15)

Some students want more than just to get good marks for the assessments, whether through generally high personal standards, “*It’s just the way I see things, right, I set the target, that’s always been high, it’s always been in my life […] All I should do; I should focus on my target and this should allow enough time and enough efforts to reach it.”* (Participant S215-17) or with a specific aim in mind; be it short term “*with this one I really tried to get my references right because I didn’t really focus on them before and I’m a little bit rubbish at getting the references correct. As in the way they’re written*” (Participant T219-04) or long term, “*I’m hoping to obtain a very solid foundation in these subjects so that I can use that for my studies for a master’s degree”*. (Participant S215-15)

Participant S215-15 had the lowest GOAL score among the four participants. They said they wanted to make ‘a better plan’ in their next module.

“*So, what really happens in my case is I don’t make plans, or I don’t make a schedule, I don’t make a timetable for myself and say this is my goal for this week or that is, you know, by the end of this month I will have finished this. Many times, it’s very instinctive. So if I open the book and I just start to read something because it seems interesting at that point and then a couple of days later I might not have finished it but I say ‘OK, now I'm going to stop and maybe just do a chapter that’s a little different’. So that’s how I tend to function.”*

Participant T219-07 had a very high GOAL score:

“*I think I set myself a variety of different types of goals based on short medium and long term. So obviously the long term being complete things like the EMA and TMA and the short term being I guess like process goals that I can work on week in and week out.”*

This student set time-related goals geared towards *“balancing work commitments and study commitments”* and said, *“The way in which I normally approach it is I will plan my week out, effectively to draw out what a perfect week for me would look like. [...] What I would do is then I would look at the*

recommended time that I should spend on each of my modules and then try and put in that plus maybe an extra ten per cent over the course of the week."

Another student talked about setting goals to match the time available for study. "*For example, if I have like, I normally have half an hour now for nothing, right, what can I do in half an hour? If I have like a big article, right, I wouldn't even take it, but if I see that in half an hour I have like little section for one page I can take that. I look through it, I learn it, right, and then when I'm doing some other activities I'm still thinking about before I go to the next section."* (Participant S215-17)

This student appreciated that the content was broken up into relatively small sections. *"The way I see it it is good that it is split. It makes it easier and it makes, it helps for time management."*

Note-making

Comments about note-making behaviour revolved around handwritten notes. Participant T219-04 said they printed out digital material to store physically "*if there was something which I felt there was loads of information in one piece of, you know, one page, or a really intricate diagram, I printed it out and inserted it into my book, which I haven't done before. ... it saves a lot of time".*

But for the main part notes were handwritten:

"*If I have the time available when going through the material I will always write notes. […] I would read through say a whole page, the equivalent of a tab, think about it and then write notes on it, then reread it and then carry on."* (Participant T219-07)

"*Well I just read it all really and just write my notes as I go along. I've got tons and tons of A4 pads and I just scribble in them*." (Participant T219-04)

It seemed to be the note-making process itself that was beneficial, rather than having the notes to refer to later:

"Well I think, for me, note taking is the fact that you have written it down and it helps you remember it better but it's not necessarily that I'll go over it again. […] I see the benefit of trying to read, think about the material, solely concentrate on that, then write down sort of what I feel I've learned from it and the takeaways. I think it's much better for my memory of it and much better to help me distil my own thoughts on the matter." (Participant T219-07)

When revising material, participants seemed to prefer going over the original material again and making more notes, rather than re-reading their own notes:

"*I do have them to go back to but, as I say, now what I do, when I'm nearing my TMA or whatever and I go over the whole block again, I write more notes. So, they've probably become useless really. […] If I have time, I will then rewrite the notes again to consolidate it. […] I was quite proud of myself the way I went through the whole block again and wrote down all the things*." (Participant T219-04)

Some participants did not tend to write separate notes but preferred to work with the original material: *"I wouldn't necessarily spend time writing things down again or making notes, handwritten notes. […] I would annotate and I would underline or I would highlight. So, something that tells me that when I go back to that page or that topic this is what I need to look at."* (Participant S215-15)

It seemed that students preferred to do this physically rather than digitally; "*Yeah, with T219 I couldn't do it but with my T213 it was a fat book, so I highlighted in the book… ."* (Participant T219-04)

This was not seen as something that needed to change: "*Things like note making, I think that's not going to change, I don't think I'm going to start making notes separately next time. Either it's probably going to be stuff that I highlight or […] but stuff that is that, you know, if I look at I will know the significance of, so that will probably not change."* (Participant S215-15)

Assessments guided note-making to some extent:

"Yeah, you've got to maybe look at your TMA or whatever first, identify what you mainly should be looking out for and so then you can be more, you know, you can write more effective note making. […] I thought: 'Oh yes they'll want to hear that and they'll want to hear that.' […] And definitely writing my points of reference for things that I think are important with my note making much more." (Participant T219-04)

Highlighting or annotating the original material also seemed to be geared towards flagging up what would be important for assessments: "*If it's studying for an exam, then I'd probably skip the stuff that I haven't previously marked and just focus on, you know, revising the concepts. Because sometimes you don't need to revisit everything if you've done it once already". (Participant S215-15)*

Relationships between learning behaviours

To investigate how learning behaviours may be related to each other, Table 6 shows the number of references coded to more than one learning attribute arranged according to which learning behaviour they are associated with. Unsurprisingly, learning attributes most frequently co-occur with learning attributes associated with the same learning behaviour, but relationships can be seen between DIGI and HELP, between GOAL and TIME, and to a lesser extent between NOTE and GOAL, NOTE and TIME, and FOCUS and TIME.

Table 6 Co-occurrence of references to learning attributes

	DIGI	ELAB	FOCUS	GOAL	HELP	NOTE	TIME
DIGI	22	2	0	2	6	2	0
ELAB	2	17	1	2	0	0	2
FOCUS	0	1	21	0	3	2	4
GOAL	2	2	0	25	0	4	8
HELP	6	0	3	0	16	0	0
NOTE	2	0	2	4	0	49	4
TIME	0	2	4	8	0	4	34

- GOAL/TIME (8): Goals often involved aiming to keep up with studies, and frequently had to be set based on the time available. Participants who discussed planning their study to match the needs of an assessment also referred to having little time to review the material.
- DIGI/HELP (6): Any interaction between students was conducted online, and participants talked about forums in the context of seeking help.

- FOCUS/TIME (4): Studying in a place where you can concentrate often means studying at a time when you can concentrate, such as before your family wakes up, or after you finish work. Participants discussed things which prevented them from concentrating, thereby taking time away time from study.
- GOAL/NOTE (4): Assessment-related goals often involved making notes as to what was important for the assessment, or re-reading or re-writing notes.
- TIME/NOTE (4): Having no time to review notes was an issue.
- FOCUS/HELP (3): Avoiding distraction by avoiding going online or interacting with other people was more likely to be discussed in the context of preferring to work alone rather than seek help.

Learning Design analysis

Initial exploration of how the learning behaviours of students may relate to learning design activity types was conducted as part of the interview analysis. Early connections were identified between certain learning behaviour attributes and the intended behaviour of students laid out in the design of an activity.

During the design and development of module materials, authors intend for students to engage with activities in a particular way to be effective. Inversely, students interact with learning content in ways that were not intended or anticipated, or a cohort of students engage with the same piece of learning in a variety of ways. This engagement was displayed on the R-Profiles, and which demonstrates that prevalent patterns of behaviour can be identified, and that these have an impact on student outcomes.

The intention of the Learning Design analysis was to triangulate the existing relationships between learning behaviours and Learning Design activity types in order to potentially augment the activity types by designing in behavioural interventions.

Relationships between learning behaviours and learning design activity types (initial interview data)

Learning Design activity types can be summarised as follows:

ACTIVITY TYPE	DEFINITION
Assimilative	Reading information, listening to it or seeing it (such as in video format) and reviewing it
Communicative	Discussing learning materials with other students and/or a tutor
Finding and handling information	Searching for new information and processing it, individually or in groups

Practice	Students apply their learning in a real-world or simulated setting
Productive	Applying knowledge and skills either individually or as a group to create a piece of work

A matrix was creating displaying the number of intersections between learning behaviours and learning design activity types (see Table 7). A lot of practical work was conducted using the VLE, so DIGI and Practice were related. Finding and Handling Information is often done online, so DIGI was related to that, and Communicative work is usually conducted digitally as well.

A strong relationship between NOTE and Productive was unsurprising as the production of notes is a fundamental part of learning. Note-making was therefore also found to be Assimilative. ELAB was strongly related to Assimilative as well, as it results in deeper learning.

GOALs were often guided by Assessment activities. Asking for HELP is necessarily Communicative, and group work was discussed in the context of being able to help each other.

Table 7 Co-occurrence of learning activities and learning behaviours

	DIGI	ELAB	FOCUS	GOAL	HELP	NOTE	TIME
Assessment	2	6	0	12	2	6	5
Assimilative	4	23	2	7	1	9	4
Communicative	5	0	0	0	8	0	0
Finding/Handling Info	9	10	1	2	0	1	1
Practice	12	1	0	2	0	2	3
Productive	1	0	2	2	0	27	2

Data collection and analysis

Content was obtained in non-interactive offline form for three of the four modules identified for this research project: TM254, T219 and S217. S215 was excluded as only one response was received to the original survey.

The content was coded first using the Learning Design Online tools to identify learning design activity types and workload. The Learning Design Tools use an algorithm for picking up on certain verb and noun combinations for determining the most likely activity types being described in the learning activities. For instance, where it finds the words “discuss” and “forum” the algorithm adds one weighting to the “communicative” activity type whereas the words “write”, and “paragraph” lead it to add one weighting to the “productive” activity type. After it analyses an activity for all these word combinations it adds up the total weightings and allocates a timing for each individual activity type based on its weighting. For example, if an activity type finds two references to communicative activity and three references to productive activity, it will allocate two-fifths of the total time to communicative and three fifths of the total time to productive.

Content was coded in NVivo for learning behaviours and learning design activity types, with a node for each of the learning behaviours (DIGI, ELAB, FOCUS, GOAL, HELP, NOTE, TIME) and for each of the 6 learning design activity types (Assessment, Assimilative, Communicative, Finding and Handling Information, Practice, Productive). In addition, the interview transcriptions were included and coded in the same way. The goal of this analysis was to identify and explore intersections between learning design activity types and learning behaviours.

Results

Coding frequency

The number of references for each node is displayed in 7 for each module. The interview coding is not represented on this table.

Table 8 Coding frequency at each node

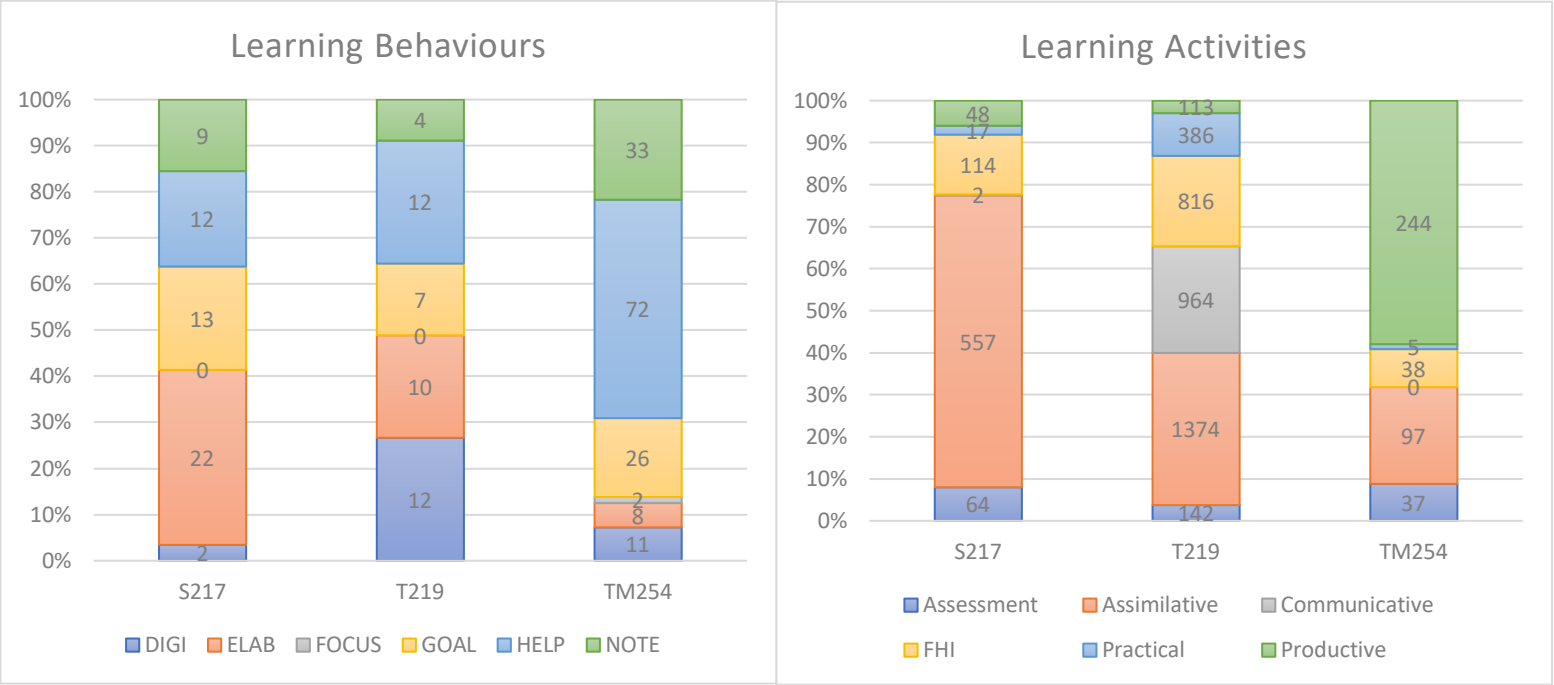
Node	S217	T219	TM254	TOTAL
Learning Behaviours	*64*	*62*	*509*	*635*
DIGI	2	12	11	2
ELAB	22	10	8	22
FOCUS	0	0	2	0
GOAL	13	7	26	13
HELP	12	12	72	12
NOTE	9	4	33	9
TIME	6	17	357	6
Learning Activities	*802*	*3795*	*421*	*802*
Assessment	64	142	37	64
Assimilative	557	1374	97	557
Communicative	2	964	0	2
Finding and Handling Info	114	816	38	114
Practice	17	386	5	17
Productive	48	113	244	48

Colour density represents how far above (red) or below (blue) the expected value the observed value is.

There were a disproportionately large number of references to TIME in TM254, as the learning design of this module helped students manage their time and set realistic time-related study goals, by accompanying every activity in the module with an estimate of the time that should be spent on it; for example, "*This activity should take you no more than*..." and, "*You should spend no more than about ... on this exercise*".

This is an example of the very different ways in which different modules choose to direct students' behaviour. The different styles of the three modules analysed are evident from the different ways the activity types and learning behaviours are distributed. These distributions are illustrated in Figure 5, with the exclusion of the TIME learning behaviour, which otherwise would overshadow the others due to the skewed number of references in TM254.

Figure 5 Distribution of coding references



Learning behaviours

What is most obvious from the learning behaviours graph in Figure 5 is that TM254 seems to have more references to HELP. By comparing the number of learning behaviour references observed for each individual module to the number we would expect given the overall proportions of learning behaviour references across all three modules[2], we find that TM254 has 1.3 times as many instances of providing information about where to find help when it is needed, such as "*if you run into problems then your tutor should be a good source of support*" and "*the TM254 Technical Help forum is a good place to raise problems and to look for advice*".

S217 does this only half as often as would be expected based on overall proportions. S217 is also only 40% or 0.4 times as likely to direct students to use a computer when there is a choice between paper or screen, and TM254 even tends to nudge students towards the opposite behaviour; "*They can be printed out as reminders, or even as places to scribble additional notes as you work on the exercises.*" ... "*You may find it helpful to print out or sketch a copy of Figure 4.3".*

Conversely, T219 activities often require students to use technology such as a digital 'DisplayWall' which therefore triggers the DIGI learning behaviour much more often (2.7 times as often as expected based on the overall proportions).

[2] To find the expected number of HELP references for TM254 for example, we find the proportion of TM254 references overall (152 TM254 references divided by 255 total references, see Figure 5), and multiply this by the number of HELP references across all 3 modules (96). Based on the overall proportions we would expect 57 HELP references for TM254, but there were 72; 1.3 times the expected number (or, 30% more than expected).

GOAL and NOTE are mentioned about as often as expected for each of the three modules, but FOCUS is not mentioned much at all in any of them. This is presumably because they are level 2 modules and students are expected to have established a study environment that works for them. There are differences however in how often students are asked to relate information to what they already know, or to connect pieces of information in order to process more deeply. S217 triggers this behaviour 2.4 times as often as expected, whereas TM254 does so much less than expected (30% or 0.3 times as often). It therefore makes sense that S217 contains 1.7 times as many Assimilative learning activity references as expected, as this type of activity is more likely to involve deeper processing.

Learning Design Activity types

The predominance of Assimilative activities in S217 is clear from the learning design activity types chart in Figure 5. We can also see immediately that TM254 has mostly Productive activities. These are referenced 7.2 times as often as would be expected based on the overall proportions, while in T219 they are referenced only 40% as often as expected. T219 appears to be a relatively practical module though (1.3 times as many references as expected) while S217 has 30% and TM254 only 10% of the expected references to practice activities. What is less obvious from the graph is that the same pattern is seen for Communicative activities; T219 had 1.3 times as many references as expected, S217 had only 1% of the expected number, and TM254 had none. While T219 seems characterised by Communicative and Practice activities, both S217 and TM254 are far more Assessment focused, having respectively 1.6 and 1.8 times as many references as expected for those activities.

Relationships between learning behaviours and learning design activity types

Incorporating the data from the coded interviews, we explored where learning activities coincided with learning behaviours, to examine the relationship between the two.

Table 9 Number of references coded at learning activities and learning behaviours

	S217						T219						TM254					
	Assessment	Assimilative	Communicative	FHI	Practice	Productive	Assessment	Assimilative	Communicative	FHI	Practice	Productive	Assessment	Assimilative	Communicative	FHI	Practice	Productive
DIGI	0	1	1	6	8	0	7	8	17	3	14	7	0	1	0	0	0	0
ELAB	3	7	0	2	1	0	4	14	2	13	3	0	0	0	0	0	0	0
FOCUS	0	1	0	1	0	1	0	1	0	0	0	1	0	0	0	0	0	0
GOAL	3	3	0	0	1	0	14	6	0	3	3	2	0	0	0	0	0	0
HELP	0	0	1	0	0	0	6	9	20	1	7	3	0	2	0	3	0	2
NOTE	0	0	0	0	0	3	4	8	2	2	4	14	1	13	0	10	0	25
TIME	4	3	0	1	0	0	6	4	0	2	5	3	1	55	0	35	4	178

Due to the inclusion of a 'time spent' estimate in every activity in TM254, there were necessarily a large number of intersections between TIME and various learning activities. Learning activities in TM254 were mainly comprised of Assimilative, FHI and Productive activity types, so these are where the intersections

occurred. Time estimates were not normally provided for assessment activities, so there is little intersection there.

NOTE co-occurred with Productive learning activities more than any other for all three modules, as note-making is a productive endeavour. T219 tended to nudge students to make notes during Assimilative activities that would help them in assessed work; *"The notes that you make on the activities will help inform your answer to the transport question in TMA 02." ... "To consolidate your learning and to aid you in your thinking for the EMA, make notes on the following questions*:"

TM254 provided a lot more direction in note-making overall, often instructing students to make notes on readings or multimedia content and directing them in how to do this. These directions were sometimes general, such as "*As you read, make brief notes on these issues*", sometimes intended simply to engage students more deeply, "*In addition to identifying the different service operation processes that are featured in the podcast, note down anything that interests or surprises you while you listen*," and sometimes very specific about the intended content of the notes, "*Summarise the situation with the 'bookings' mailbox, taking particular note of any quantitative information you can glean from the scenario", "Make brief notes on the kinds of data you have stored and how you back them up",* and *"write down a list of the outcomes that Ben was aiming to offer, and to whom".*

Because TM254 tended to directly trigger note-taking behaviour, NOTE intersected with Assimilative and FHI as well as Productive activities. Some module designers may consider note-making a personal choice, both in terms of whether and how to make notes, but some students may need more direction to improve their note-making and would benefit from an approach like that of TM254.

T219 involved a lot of online group-work, and students were often encouraged to help each other, so HELP intersected with several types of activity in that module, but primarily with Communicative activities, as helping each other online or seeking help via a forum is a Communicative endeavor: *"It might be useful to discuss your answer with other students on the T219 cafe forum [...] sharing those with other students on the DisplayWall will give you the chance to get comments from other people upon whether your diagram's useful or the ways in which you could have done it differently."*

In TM254, HELP intersected with Assimilative, FHI and Productive learning activities due to direct suggestions about help-seeking, rather than encouragement to help each other: " *If you find that the glossaries have not made something clear, ask your tutor to explain any problematic concepts on the tutor group forum. […] If there are still problems that the above didn't fix, then raise them in the Technical Help forum and we'll work them through."*

Goals were often guided by Assessment activities for S217 and T219, though not for TM254, and the focus on online group work resulted in an association between DIGI and various learning activities on both these modules. A lot of practical work was conducted using the VLE, and this mainly involved Communicative activities, so both were related to DIGI. Some of this work was assessed, accounting for an association between Assessment and DIGI for T219.

Finding and handling information is often done online as well, and students are occasionally directly told to use technology to seek information: *"Search for a few environmental management timelines on the internet. Note: you may have more luck using a search term of 'environmental timeline'. There are more of these general timelines to choose from, and you will probably find the additional content to be of interest!"*

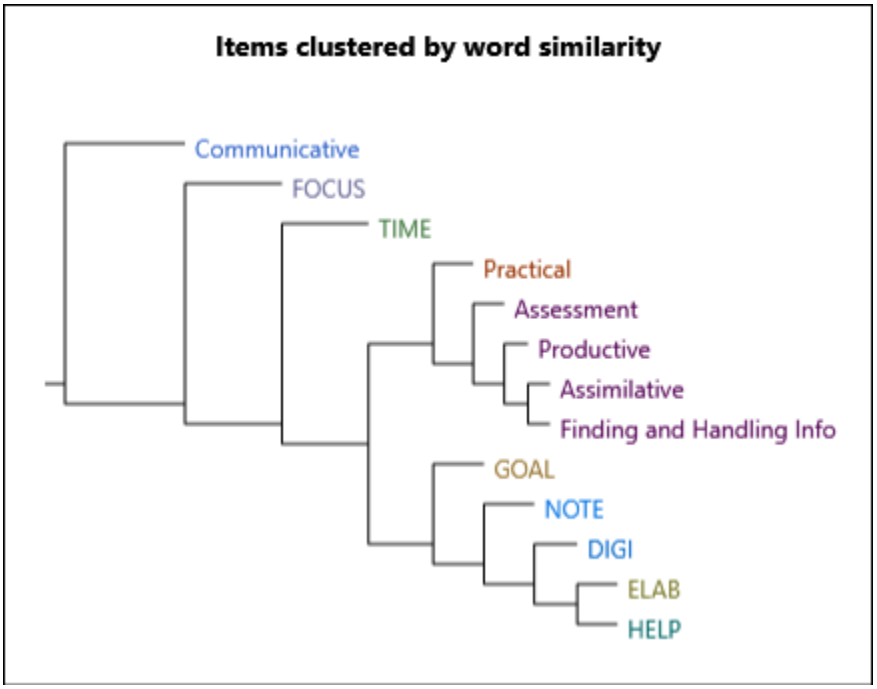
TM254 had very little reference to DIGI behaviours in the learning activities, and in fact the writers seem to push students away from using technology when there is a choice, *"You may find it helpful to print out Table 3.2, or note down the details*" but this may be because the module content is such that students have no choice but to constantly use technology, so when there is a choice, using paper may provide some balance.

The expected association between ELAB and Assimilative learning activities was found for S217 and T219, but not for TM254. In general, TM254 seems to direct students to do things a certain way, rather than encouraging them to link their knowledge with other knowledge or previous experience. Triggering ELAB behaviours need not be restricted to certain types of module; students can be helped to process any information more deeply simply by reframing the way an exercise is set out. An exercise in S217 for example asks students specifically to use their prior experience and observations to answer questions about the force required to move objects across different surfaces. The questions are very simple, and the 'prior experience' in question is merely a basic understanding of the world, but as every student has this prior knowledge, every student can then see how difficult equations and formulae are related to the simplest of observations, grounding the abstract concepts in a concrete foundation.

Additional similarities between learning behaviours and learning design activity types

Another method of exploring similarities between learning behaviours and activities is to examine the similarity of words in references coded to each learning behaviour or activity. Figure 6 shows items clustered by the similarity of the words within the references pertaining to each item.

Figure 6 Items clustered by word similarity



It makes sense that Assimilative and Finding and Handling Info are closely related, as one must find and handle information before assimilating it. One then produces notes to aid assimilation and prepare for assessments, so Productive is related to the Assimilative and FHI cluster, and Assessment is related to this cluster of three.

It is surprising that ELAB is not related to Assimilative, as both share similar motivations. In fact, it appears that, in terms of word similarity, most learning behaviours are only related to other learning behaviours, and many activities are only related to activities. However, the activities FOCUS and TIME, and the learning behaviour Communicative, do not follow this pattern, and seem to stand alone, with little similarity to any other learning behaviour or activity.

TIME for example seems just as closely related to other learning behaviours as it is to other activities. This is particularly interesting given the association between TIME and many learning behaviours, especially within TM254.

FOCUS seems to be distinguished mainly by having very few references at all; as previously discussed, these are not entry-level modules, and students are presumably expected to know how to create a positive study environment already.

Communicative only shares references with learning activities on T219. It should be pointed out that coding of references cannot be entirely free from experimenter bias, as the person doing the coding may have preconcieved notions which cause them to interpret something as pertaining to a certain learning activity or behaviour, while another coder might not share their view.

Word similarity clustering, as a technique, should reduce this bias somewhat, as even though the references have been allocated by a potentially biased method, their content was not created by the coders and therefore does not share this bias. One potential avenue for future research might be for those who created the content to code the material as they intended it to function, eliminating potential errors in coding which might increase bias.

Learning Behaviours and successful outcomes

As a result of the low populations of the STEM modules selected for the project and the resultant low response rates, the research team revisited the 2017 Learning Behaviours of OU Students data, including the outcomes data for those students to 2020. The success factor focused on specifically was progression.

The progression rates differ between the clusters in the original 2017 data. The chart columns represent students who studied 2017J as their first and only module so far within the OU (i.e. no progression, N=66) and those for whom 2017J was the first of at least two modules studied (i.e. some progression, N=233). The second chart, showing these as percentages, hints at differing proportions between clusters. The expected numbers of progressing and non-progressing students in each cluster can be calculated by assuming equal numbers across clusters (see Table A).

A chi-square test may then be carried out to compare the assumed distribution with the actual one. Results show that the hypothesis that progressing and non-progressing students are equally distributed across clusters can be rejected at $p<0.05$. This indicates that some clusters have more progressing students than you might expect, and some have fewer. Clusters 1 and 2 have a higher proportion of students who progress. Cluster 2 has a lower proportion of students who do not progress. So, students

in Cluster 2 might be regarded as more likely to progress than students in other clusters. This is a tentative conclusion, because there are potential confounding factors. It does suggest that further work may be helpful, with a larger dataset and more sophisticated statistical analysis.

Brief description of Cluster 2 (N=135)

Cluster 2

Very high score:	GOAL HELP NOTE
High score:	ELAB TIME
Average score:	FOCUS
Low score:	DIGI
Very low score:	

Overall, the learning behaviour concept scores for this group are high. In particular, members of this group have very high scores for GOAL, HELP, NOTE and high scores for ELAB and TIME. These students appear to be goal-oriented, help-seeking and generally tend to be on schedule with their studies. They make many notes and link new information to ideas already known. They tend to seek extra information.

These students have low DIGI scores, and have average technological self-efficacy. This group has the highest percentage accessing content using a mix of media, with a low percentage of students who mainly access content digitally.

The age profile of this group is younger than the cohort, with a high percentage in the 26 to 35 year age group. There is a higher percentage of females than in the cohort. This is the largest group, comprising 26% of the cohort.

There is a higher percentage of new postgraduate students than in the cohort, with the lowest percentage of STEM students of all the groups. Motivation is similar to that of the whole cohort.

Progression against individual learning behaviours was also analysed. This does not indicate any results of interest at this stage. The clusters show more promise than the individual learning behaviours when exploring progression.

Once radar diagrams had been identified in the 2020 data, the numerical values of each score were used to define R-profiles. These were then applied to the 524 results from the 2017 survey. To simplify the

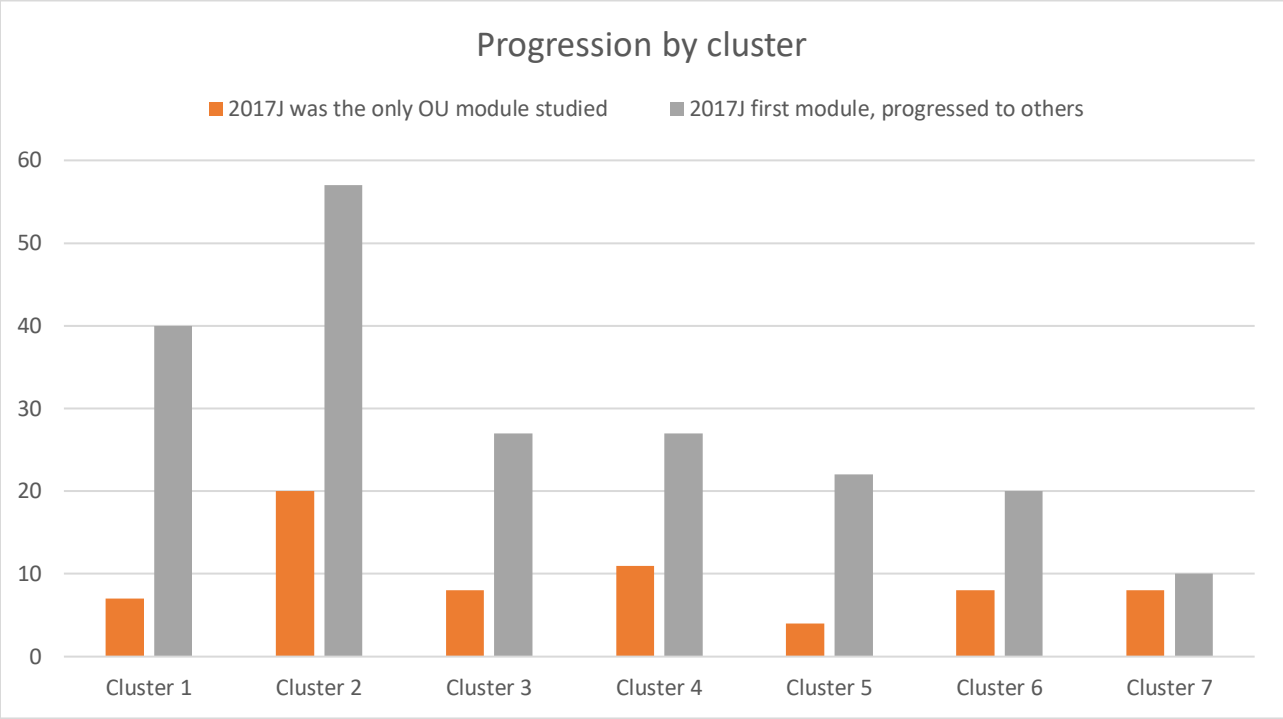
analysis, the standardised scores were further categorised into bands A to F (high to low values). Using filters and pivot tables, each of the 524 results could then be allocated a profile. This was carried out for most of the 524 results. About one third of the results were not classified in this way, because they represented novel shapes not present in the 2020 data.

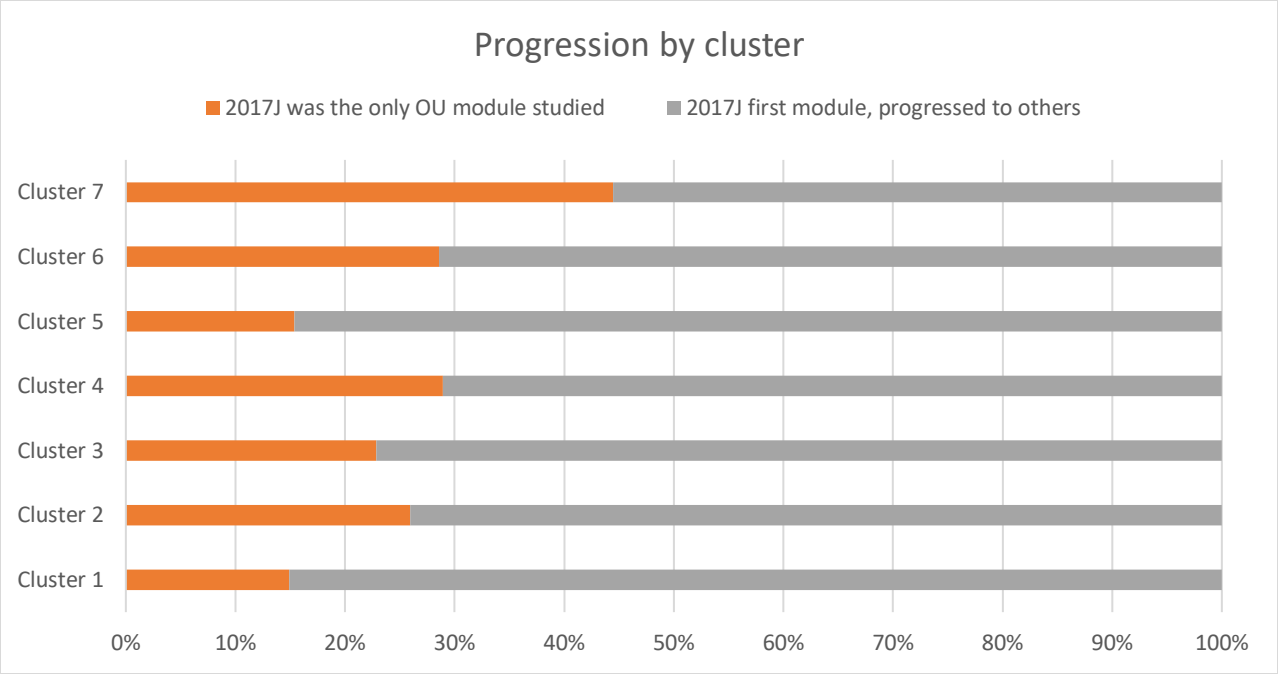
Where there were sufficient results in a single profile, descriptive and analytic statistics were used to explore whether there were any underlying patterns in progression or use of digital technology compared with technological self-efficacy. The results are inconclusive, mainly due to low numbers in each of the subsets. There do appear to be some profiles that are more prevalent than others, so there is an indication that these R-Profiles represent some authentic combinations of learning behaviours. Hence, they may be helpful in exploring student behaviours from a different perspective than either the statistically determined clusters or the individual learning behaviours.

Comparing experience and progression categories: original clusters from 2017 survey

Charts

Note that there are unequal numbers of students in each cluster, so the second chart (percentage bar) is a better representation of the differences between the progression rates for each cluster.





Chi-square test

If we assume that progression rates are similar across all clusters, it is possible to carry out a Chi-square test to compare the actual values with these assumed values. The numbers of students in each cluster are not equal.

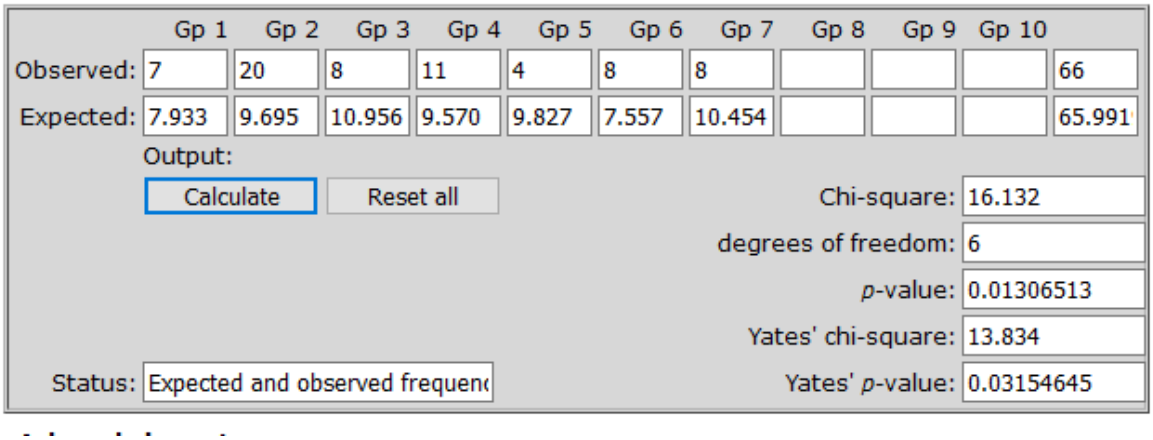
Table 10

Cluster	1	2	3	4	5	6	7	TOTAL
N	63	77	87	76	78	60	83	524
N/524	0.1202	0.1469	0.1660	0.1450	0.1489	0.1145	0.1584	1
Non-progress actual	7	20	8	11	4	8	8	66
Non-progress expected	7.933	9.695	10.956	9.570	9.827	7.557	10.454	66
Progress actual	40	57	27	27	22	20	10	203
Progress expected	24.401	29.821	33.698	29.435	30.227	23.244	32.155	203

The results are presented below[3]. These show that the numbers of students

[3] Using Chi-square calculator at http://quantpsy.org/chisq/chisq.htm

Students who did not progress. Significant at p<0.05. We can reject the hypothesis that non-progressing students are distributed evenly between the clusters.



	Gp 1	Gp 2	Gp 3	Gp 4	Gp 5	Gp 6	Gp 7	Gp 8	Gp 9	Gp 10	
Observed:	7	20	8	11	4	8	8				66
Expected:	7.933	9.695	10.956	9.570	9.827	7.557	10.454				65.991

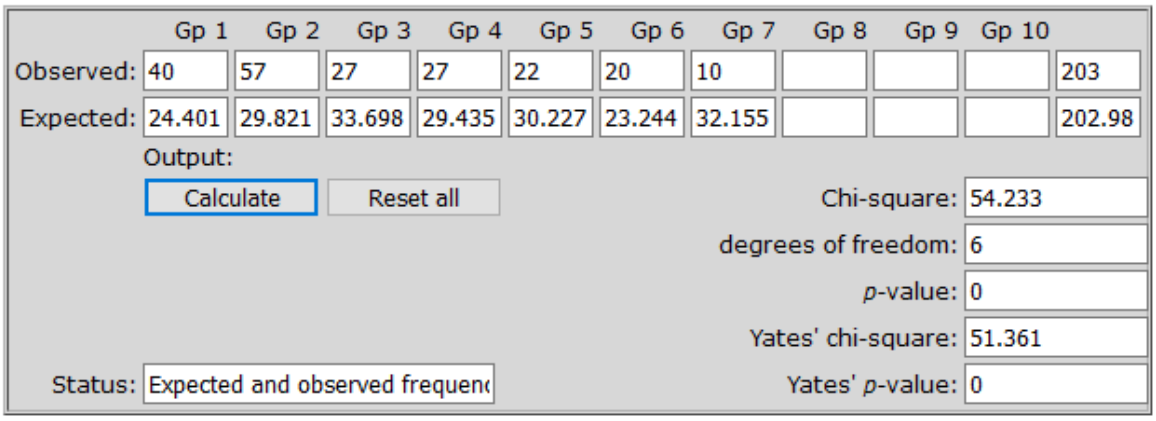
Output:

Calculate | Reset all

Chi-square:	16.132
degrees of freedom:	6
p-value:	0.01306513
Yates' chi-square:	13.834
Yates' *p*-value:	0.03154645

Status: Expected and observed frequen

Students who did progress. Significant at p<0.05. We can reject the hypothesis that progressing students are distributed evenly between the clusters.



	Gp 1	Gp 2	Gp 3	Gp 4	Gp 5	Gp 6	Gp 7	Gp 8	Gp 9	Gp 10	
Observed:	40	57	27	27	22	20	10				203
Expected:	24.401	29.821	33.698	29.435	30.227	23.244	32.155				202.98

Output:

Calculate | Reset all

Chi-square:	54.233
degrees of freedom:	6
p-value:	0
Yates' chi-square:	51.361
Yates' *p*-value:	0

Status: Expected and observed frequen

Comparing experience and progression categories: individual learning behaviours from 2017 survey

Charts for each of the Learning Behaviours in turn are shown on the following pages. The key question is are there any differences in the shape of the distribution between the three charts for each behaviour, in particular between the first and last graphs.

The first graph shows the weighted means for each of the categories, from the data table below. The key question here is: are the heights of the bars different within each LB? If so, is the difference statistically significant?

As you can see from the other graphs below, these distributions are skewed (not symmetrical) so we cannot assume a normal distribution, so we need a non-parametric test. The Mann-Whitney U test is appropriate. Looking at the individual LB charts on the following pages, FOCUS seems a good candidate to see a statistically significant difference between 'only module studied' and 'first module studied'. A

manual calculation of U gives a U value of 6412.5 for 'only module studied' and a z score of -0.52093 for the comparison with 'first module studied'. As z is less than -1.96, we cannot reject the null hypothesis (assuming calculations correct). That is, there appears to be no statistically significant difference between the FOCUS value for those who only studied 2017J and those who went on to other modules.

The median value of FOCUS for the group who only did 2017J is 0.71

The median value of FOCUS for the group who continued 2017J is also 0.71

Visual comparison of the heights of the columns in the first chart suggests that there are unlikely to be any other differences with statistical significance.

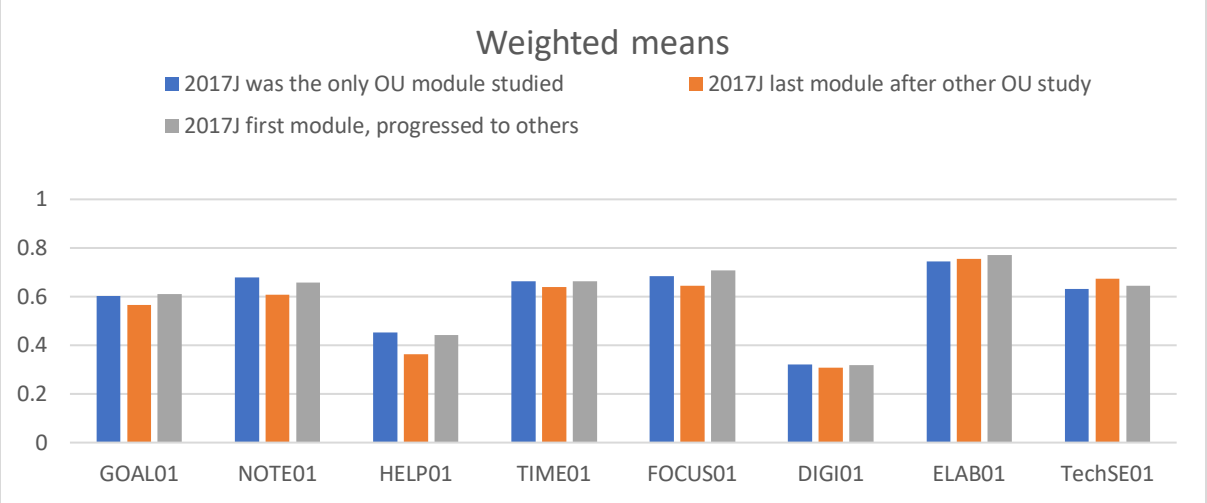
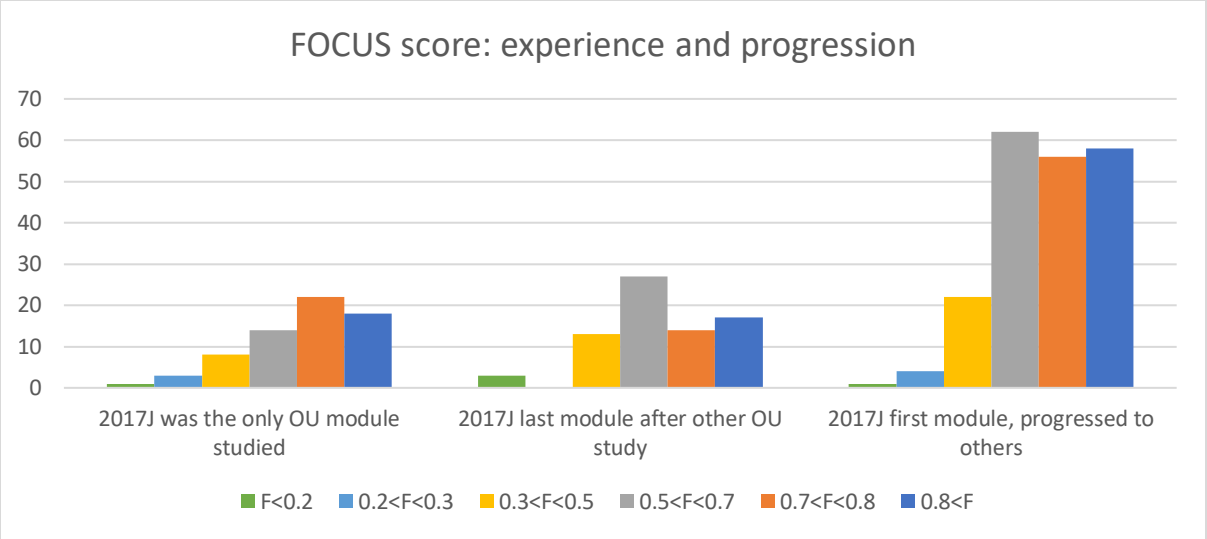
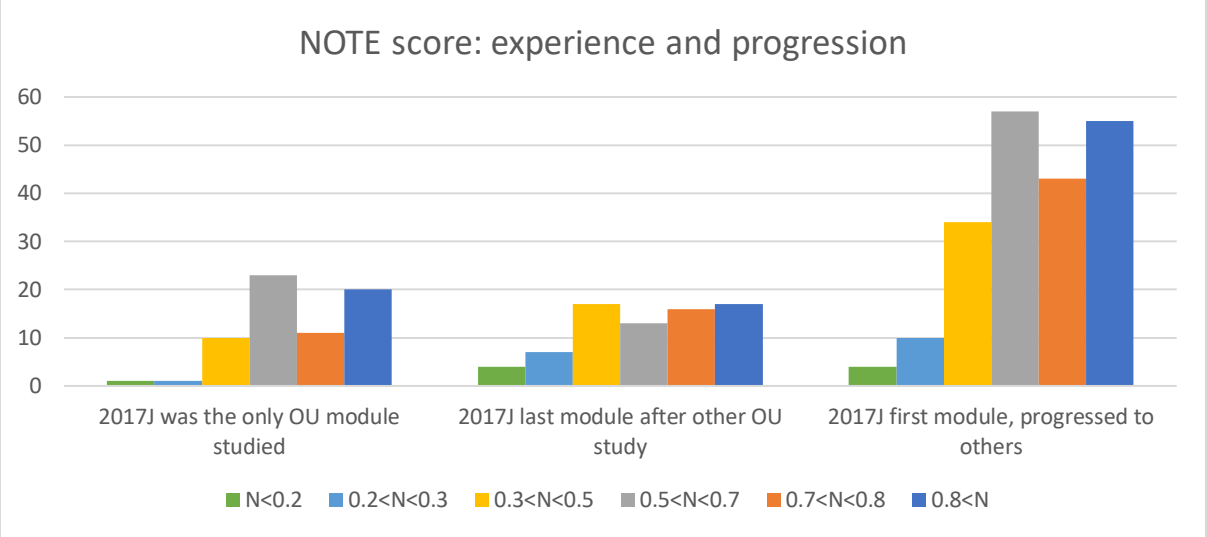
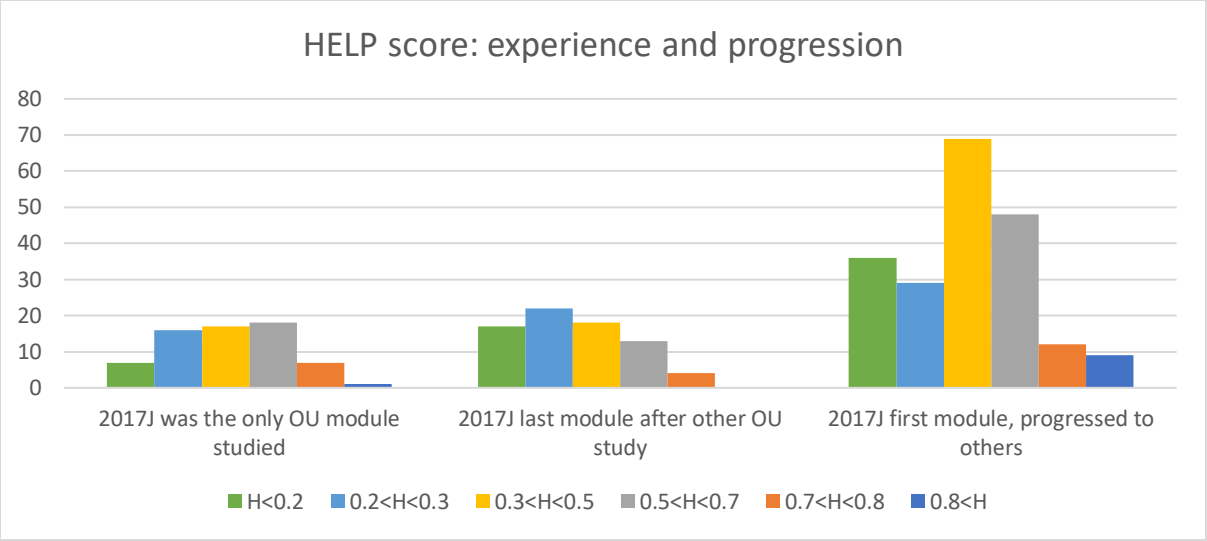


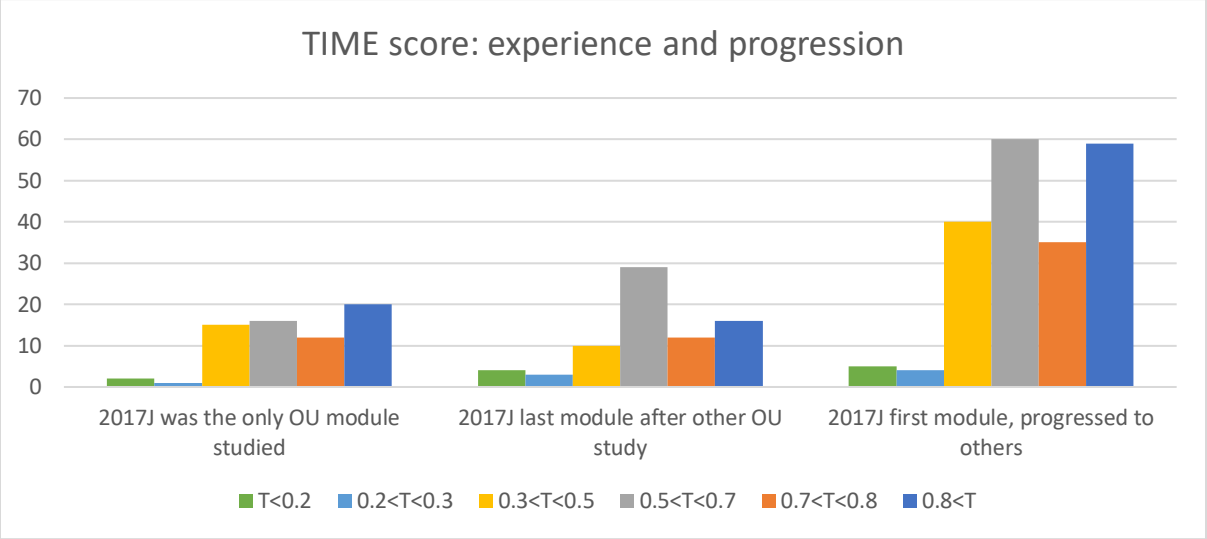
Table 11

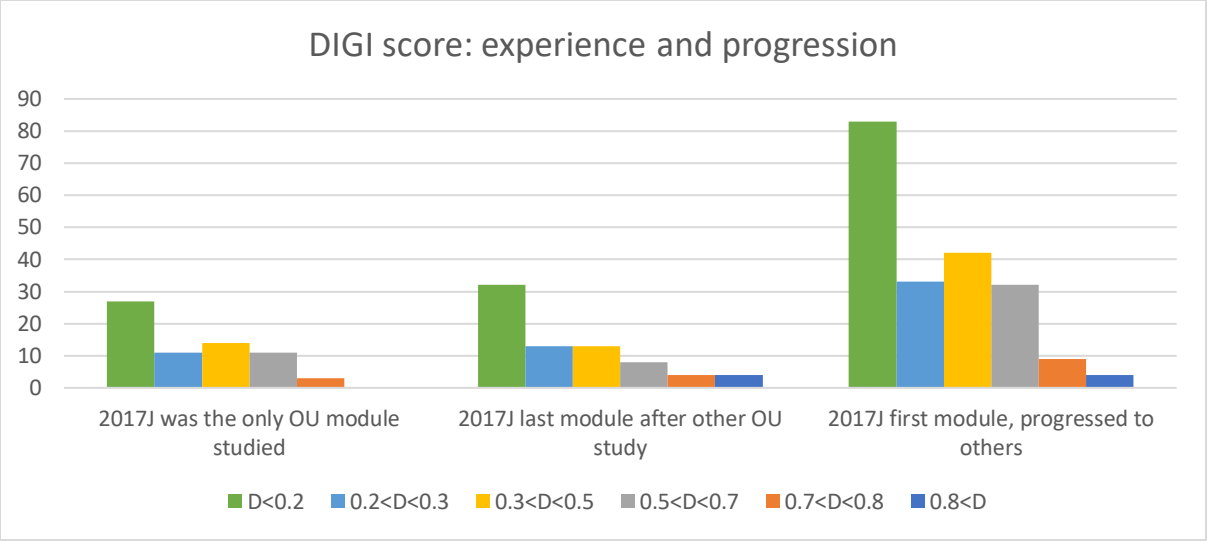
	2017J was the only OU module studied	2017J last module after other OU study	2017J first module, progressed to others
	Weighted Mean	Weighted Mean	Weighted Mean
GOAL01	0.602813853	0.565637066	0.610661506
NOTE01	0.680194805	0.608590734	0.657107671
HELP01	0.451515152	0.364189189	0.443103448
TIME01	0.663825758	0.640202703	0.662253695
FOCUS01	0.683080808	0.644707207	0.708128079
DIGI01	0.321969697	0.307432432	0.318719212
ELAB01	0.744318182	0.754222973	0.771243842
TechSE01	0.631313131	0.672458172	0.643912738
Total number of cases N	66	74	203

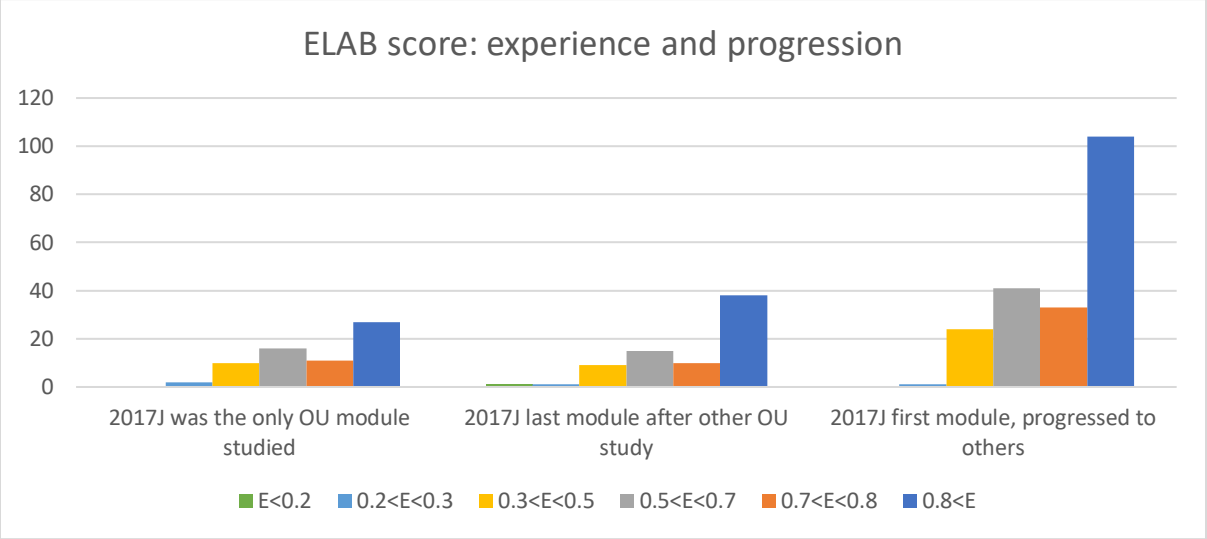

FOCUS score: experience and progression
70
60
50
40
30
20
10
0
2017J was the only OU module studied
2017J last module after other OU study
2017J first module, progressed to others
F<0.2
0.2<F<0.3
0.3<F<0.5
0.5<F<0.7
0.7<F<0.8
0.8<F

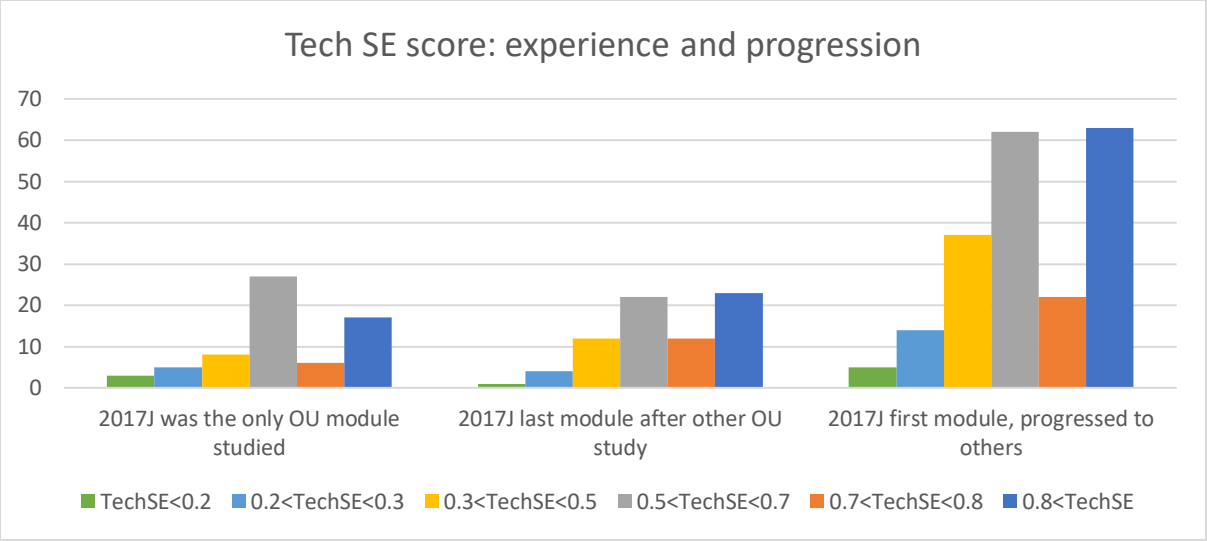

NOTE score: experience and progression
60
50
40
30
20
10
0
2017J was the only OU module studied
2017J last module after other OU study
2017J first module, progressed to others
N<0.2
0.2<N<0.3
0.3<N<0.5
0.5<N<0.7
0.7<N<0.8
0.8<N


HELP score: experience and progression
80
70
60
50
40
30
20
10
0
2017J was the only OU module studied
2017J last module after other OU study
2017J first module, progressed to others
H<0.2
0.2<H<0.3
0.3<H<0.5
0.5<H<0.7
0.7<H<0.8
0.8<H


TIME score: experience and progression
70
60
50
40
30
20
10
0
2017J was the only OU module studied
2017J last module after other OU study
2017J first module, progressed to others
T<0.2
0.2<T<0.3
0.3<T<0.5
0.5<T<0.7
0.7<T<0.8
0.8<T


DIGI score: experience and progression
90
80
70
60
50
40
30
20
10
0
2017J was the only OU module studied
2017J last module after other OU study
2017J first module, progressed to others
D<0.2
0.2<D<0.3
0.3<D<0.5
0.5<D<0.7
0.7<D<0.8
0.8<D

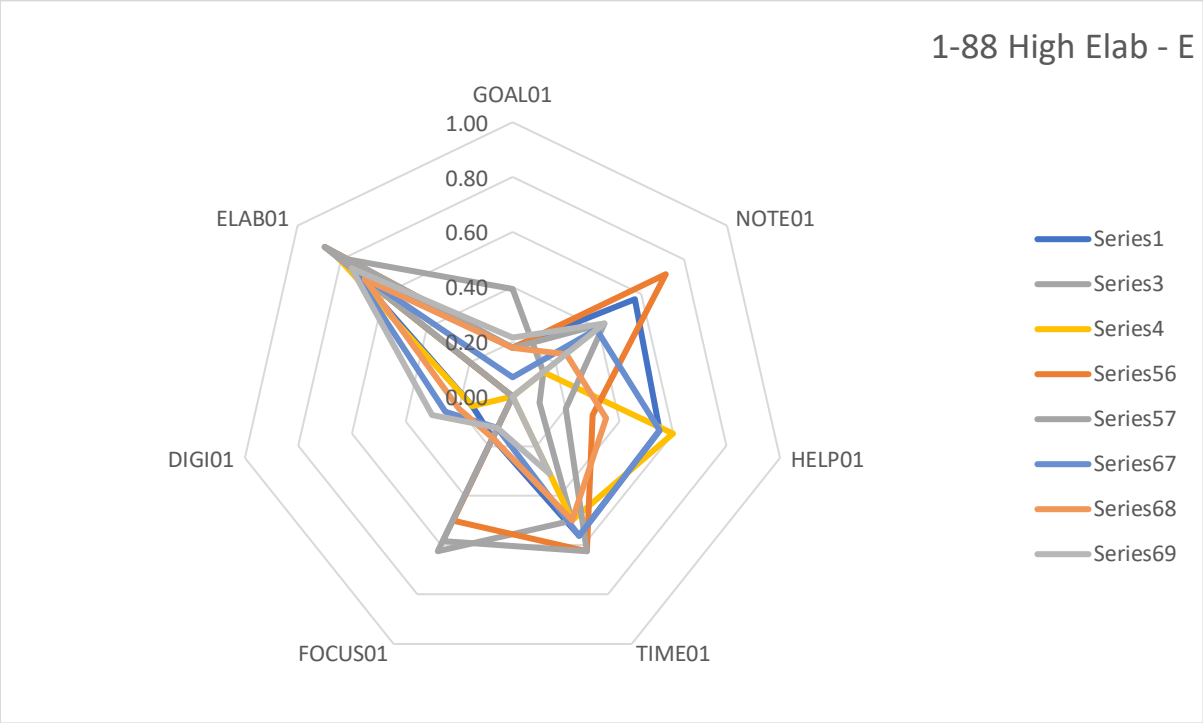

ELAB score: experience and progression
120
100
80
60
40
20
0
2017J was the only OU module studied
2017J last module after other OU study
2017J first module, progressed to others
E<0.2
0.2<E<0.3
0.3<E<0.5
0.5<E<0.7
0.7<E<0.8
0.8<E



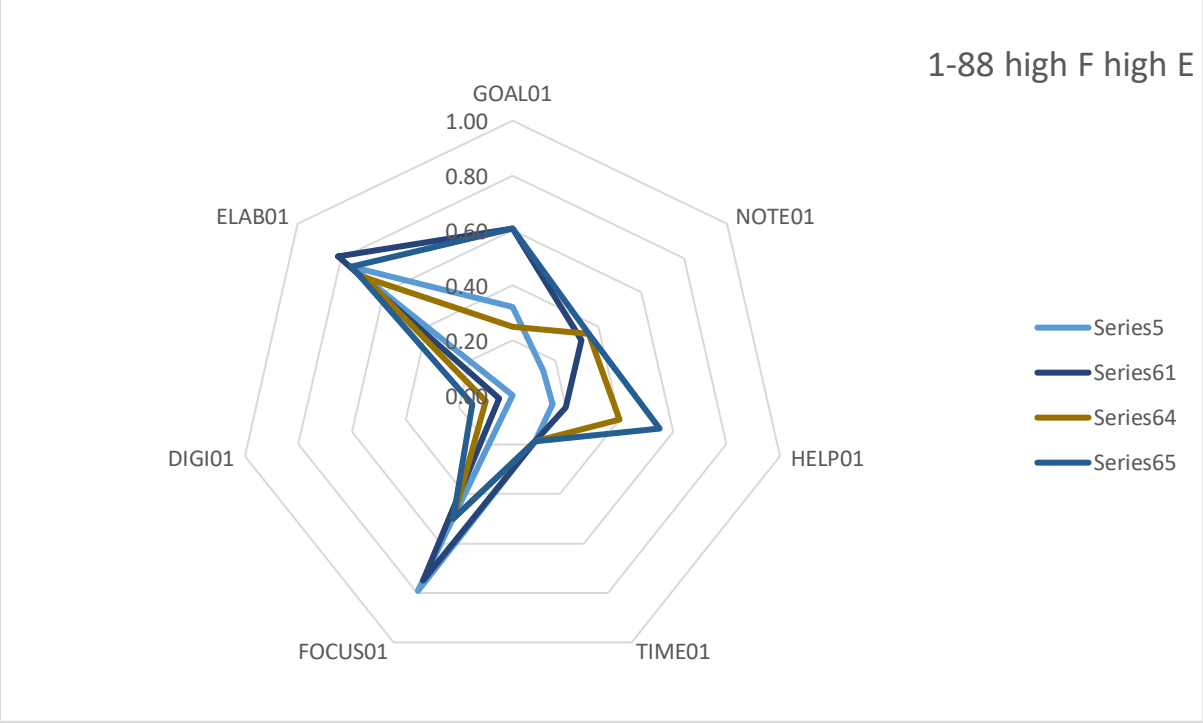
R-profiles groups from 2017 survey

This is a selection of some profiles discovered in the 524 responses to the original 2017 survey. Excel only allows radargrams to have a limited number of data series, so these are split into different sections of the data, i.e. series 1-88, 89-248. The data were pre-sorted according to highest DIGI, FOCUS values.

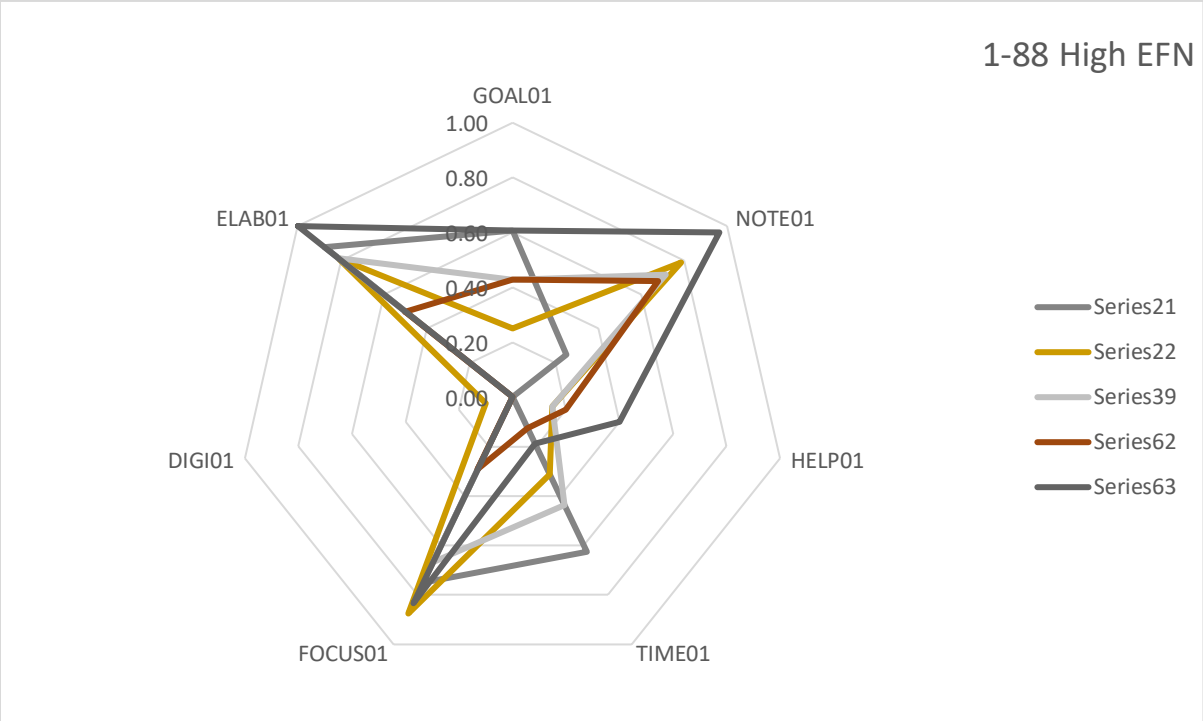
A single behaviour has a high value: High Elaboration



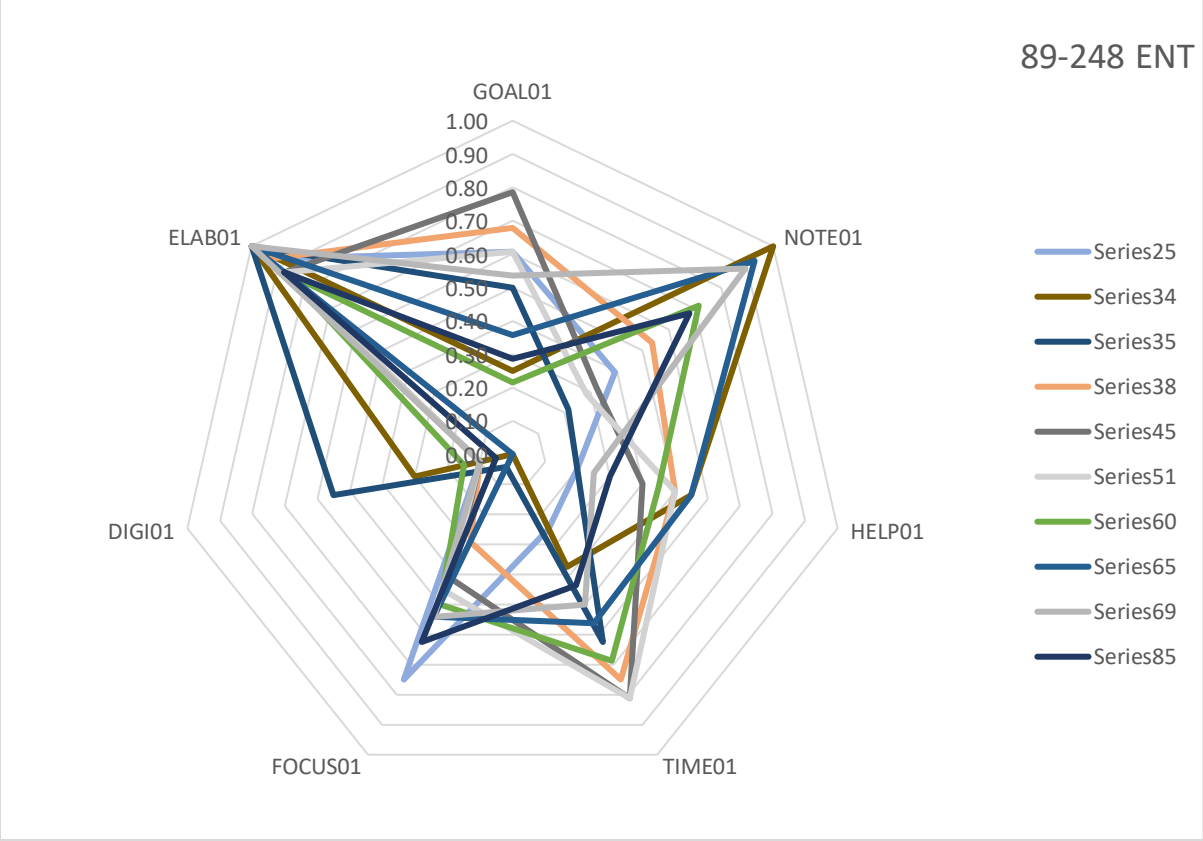
Two behaviours have high values: High Elaboration, High Focus



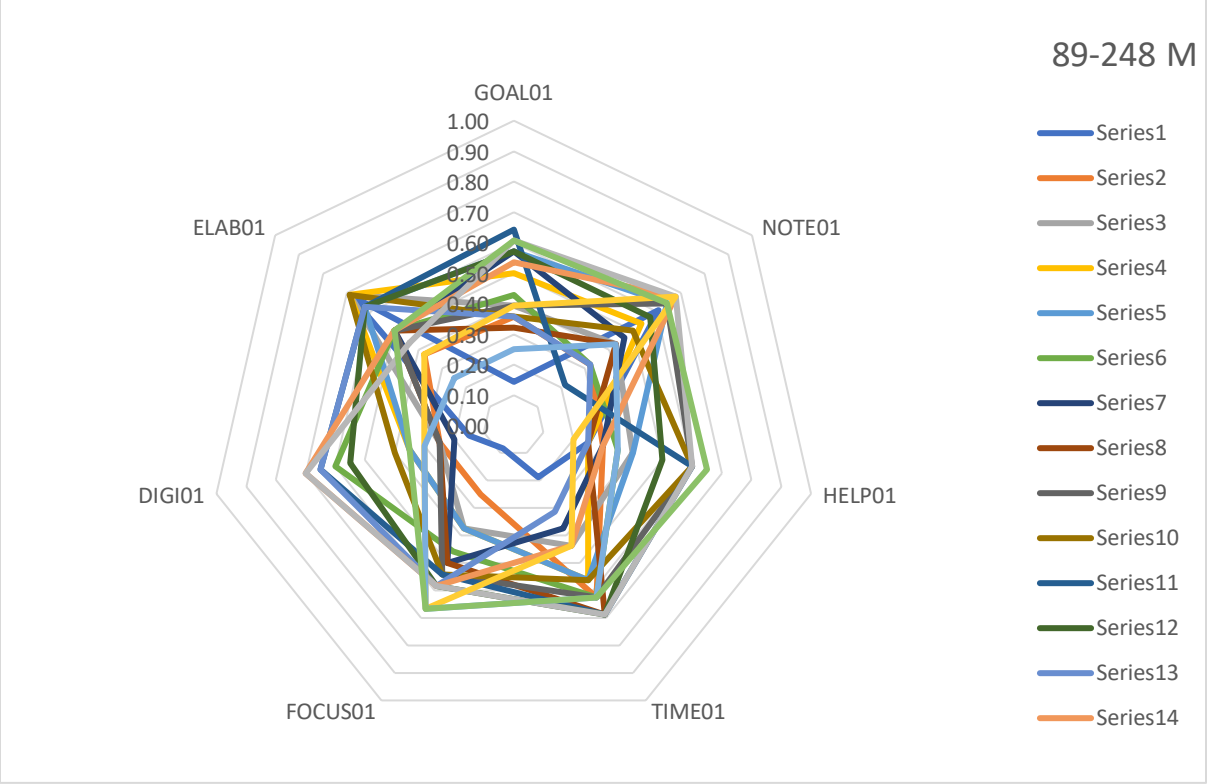
Three behaviours have high values: High Elaboration, Note making and Focus



High Elaboration, Note making and Time

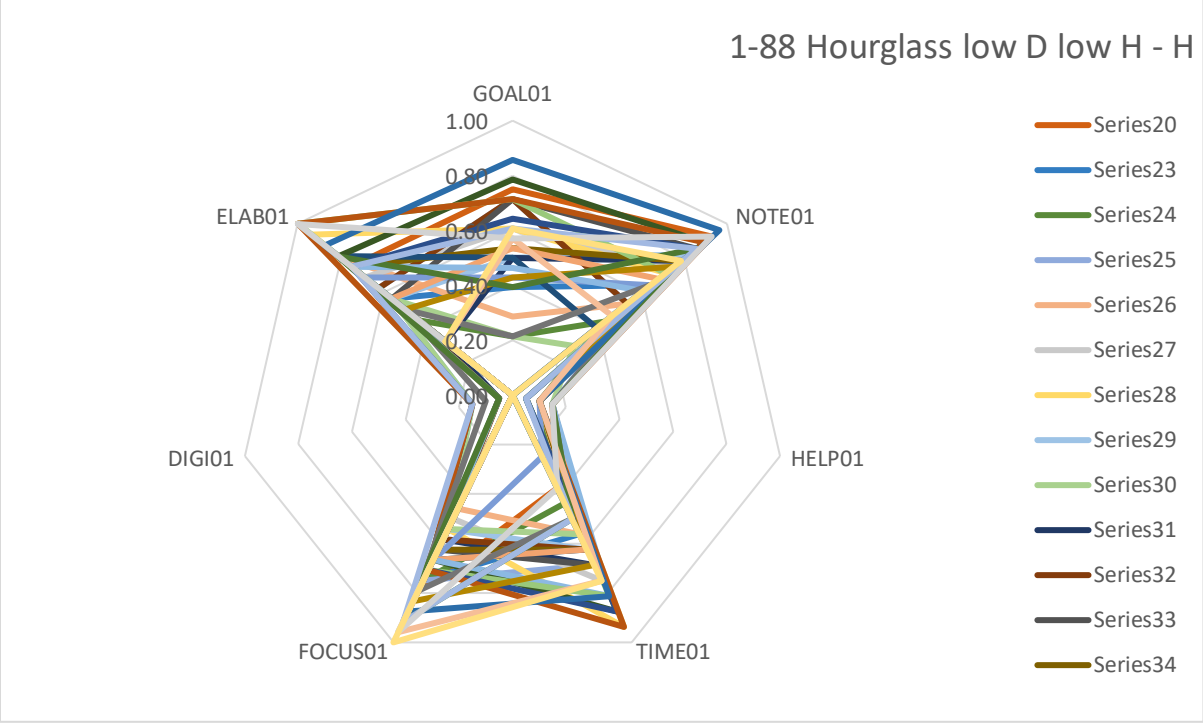


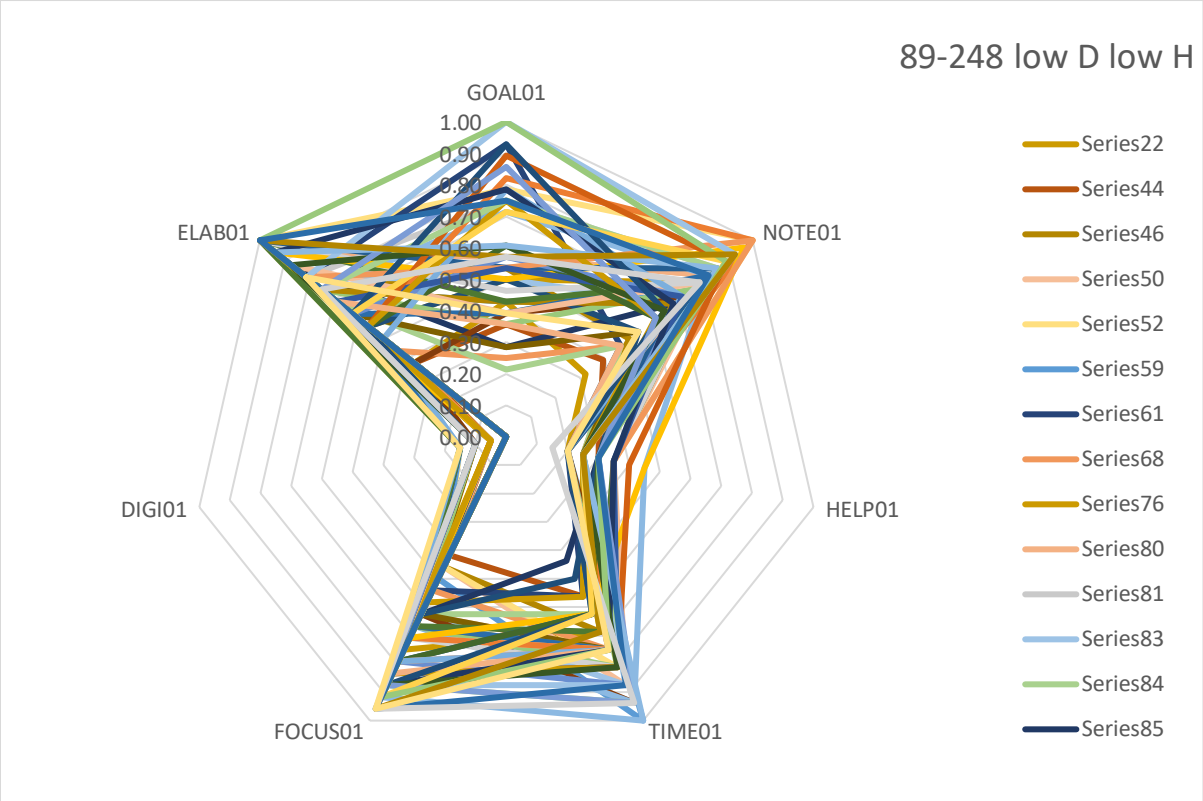
All behaviours have moderate values below 0.7



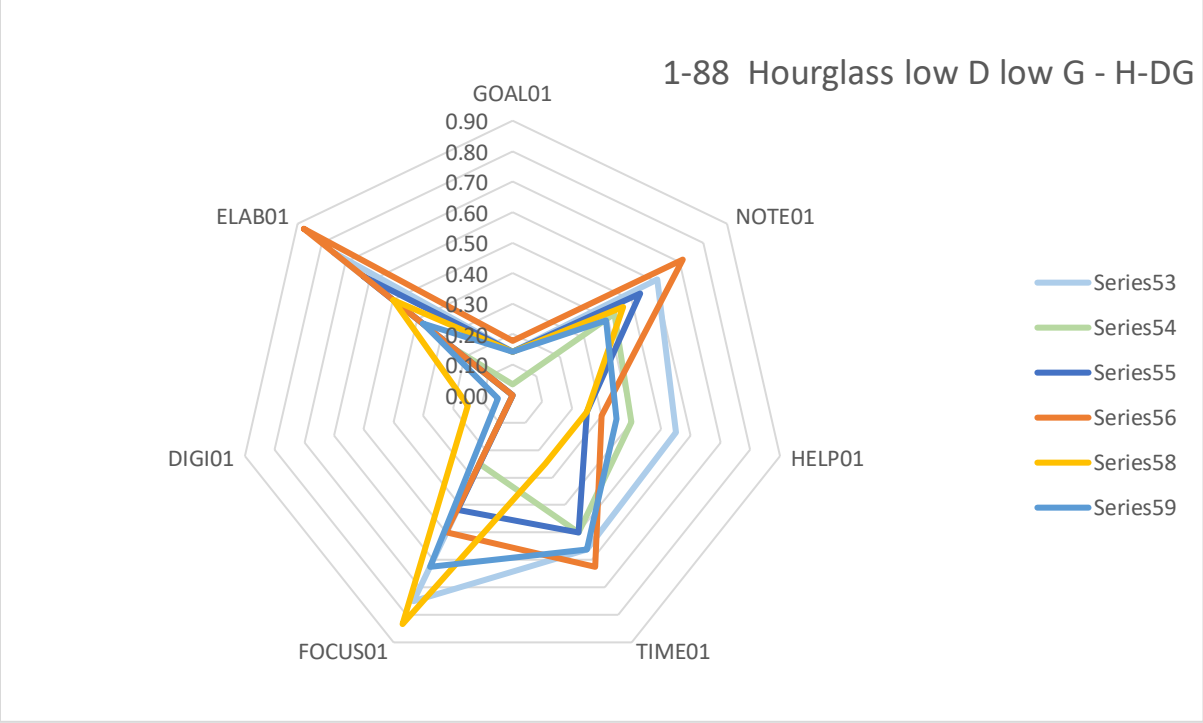
One behaviour has a low value below 0.3: low DIGI

Two behaviours have low values: Low DIGI, low HELP





Low Digi, low Goal setting



Conclusions

By designing interventions and deploying these through module content, individual students and cohorts of students could be encouraged to undertake behaviours that would lead to more successful outcomes.

Students who demonstrate learning behaviours could be likelier to progress

As a result of the low populations of the STEM modules selected for the project and the resultant low response rates, the research team revisited the 2017 Learning Behaviours of OU Students data, including the outcomes data for those students to 2020. The success factor focused on specifically was progression.

One particular cluster of students from this cohort displayed higher rates of progression. Overall, the learning behaviour concept scores for this group were high. In particular, members of this group hade very high scores for GOAL, HELP, NOTE and high scores for ELAB and TIME. These students appeared to be goal-oriented, help-seeking and generally tend to be on schedule with their studies. They made many notes and linked new information to ideas already known. They tended to seek extra information.

These students had low DIGI scores, and had average technological self-efficacy.

Relationships exists between learning behaviours (certain behaviours trigger each other)

Table 6 demonstrated how learning behaviours may be related to each other, showing the number of references coded to more than one learning attribute arranged according to which learning behaviour they are associated with. Unsurprisingly, learning attributes most frequently co-occur with learning attributes associated with the same learning behaviour, but relationships can be seen between DIGI and HELP, between GOAL and TIME, and to a lesser extent between NOTE and GOAL, NOTE and TIME, and FOCUS and TIME.

Learning behaviours are present in the learning design of modules and could trigger specific behaviours in students

During the design and development of module materials, authors intend for students to engage with activities in a particular way to be effective. Inversely, students interact with learning content in ways that were not intended or anticipated, or a cohort of students engage with the same piece of learning in a variety of ways. This engagement was displayed on the R-Profiles, and which demonstrates that prevalent patterns of behaviour can be identified, and that these have an impact on student outcomes.

The intention of the Learning Design analysis was to triangulate the existing relationships between learning behaviours and Learning Design activity types in order to potentially augment the activity types by designing in behavioural interventions.

References

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Ellis, Elizabeth; Gallagher, Alice and Peasgood, Alice (2017). Study behaviours in an increasingly digital world: Learning habits, top tips and 'study hacks' questionnaire survey. The Open University. Retrieved 24 December 2020 (http://oro.open.ac.uk/50433/)

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Appendices

Appendix A: Metrics for project

Appendix C: StudyHabitsSTEM-survey-instrument

Appendix D: Interview Schedule

Deliverables

Behavioural Insights Infographic

STEM Project Infographic