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### Citation for published version:

Robertson, K, Hughes, K & Rhind, S 2024, 'Embedding assessment literacy can enhance graduate attribute development in a Biomedical Sciences curriculum', *British journal of biomedical science*, vol. 81, pp. 1-17.  
<https://doi.org/10.3389/bjbs.2024.12229>

### Digital Object Identifier (DOI):

[10.3389/bjbs.2024.12229](https://doi.org/10.3389/bjbs.2024.12229)

### Link:

[Link to publication record in Edinburgh Research Explorer](#)

### Document Version:

Peer reviewed version

### Published In:

British journal of biomedical science

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# Embedding assessment literacy can enhance graduate attribute development in a Biomedical Sciences curriculum Authors

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*Submitted to Journal:*  
British Journal of Biomedical Science

*Article type:*  
Original Research Article

*Manuscript ID:*  
12229

*Received on:*  
13 Oct 2023

*Revised on:*  
05 Apr 2024

*Journal website link:*  
[www.frontierspartnerships.org](http://www.frontierspartnerships.org)

In review

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### *Conflict of interest statement*

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest

### *Author contribution statement*

KR conceived and conducted the study, collected, and analysed the data and wrote the manuscript. KH performed the study and analysed the data. SR contributed to the development of the study themes, critically guided the study, and reviewed the data. All authors reviewed and edited the final submitted manuscript.

### *Keywords*

assessment literacy, Graduate attributes, Biomedical Sciences, feedback, peer assessment

### *Abstract*

Word count: 344

This paper describes the successful implementation of an assessment literacy strategy within a Biomedical Sciences degree. Teaching was aligned with an assessment literacy framework and aimed to prepare undergraduates for a literature comprehension assessment. Students were introduced to the assessment purpose and an adapted Miller's pyramid model illustrated how the assessment contributed to competency development during their degree. Students read primary research papers and answered questions relating to the publications. They were then introduced to the processes of assessment and collaboratively graded answers of different standards. Finally, student and faculty grades were compared, differences considered, and key characteristics of answers discussed. Most students reported that they understood more about assessment standards than prior to the intervention (139/159 (87.4%)) and felt it had helped prepare them for their exam (138/159 (86.8%)). The majority also reported they had increased confidence in evaluating data (118/159 (74%)), communicating their reasoning (113/159 (71%)) and considering what a reader needs to know (127/159 (79.9%)). Students were asked to state the most important thing they had learned from the assessment literacy teaching. Notably, no responses referred to domain-specific knowledge. 129 free text responses were mapped to the University of Edinburgh graduate attribute framework. 93 (72%) statements mapped to the graduate attribute category "Research and Enquiry", 66 (51.16%) mapped to "Communication" and 21 (16.27%) mapped to "Personal and Intellectual Autonomy". To explore any longer-term impact of the assessment literacy teaching, a focus group was held with students from the same cohort, 2 years after the original intervention. Themes from this part of the study included that teaching had provided insights into standards and expectations for the assessment and the benefits of domain specific knowledge. A variety of aspects related to graduate attributes were also identified. Here, assessment literacy as a vehicle for graduate attribute development was an unexpected outcome. We propose that by explicitly engaging students with purpose, process, standards, and expectations, assessment literacy strategies may be used to successfully raise awareness of developmental progression, and enhance skills, aptitudes, and dispositions beneficial to Biomedical Sciences academic achievement and life after university.

### *Contribution to the field*

The use of primary research literature is integral to all Biomedical Science (BMS) practice. In Edinburgh, the teaching of primary 'literature comprehension' to BMS students begins early in their degree. In 2019, to improve this teaching, we adopted an 'assessment literacy' approach to proactively engage students with the purpose and processes of a literature comprehension assessment. Students read research papers and answered questions relating to these. They were then introduced to the processes of assessment and collaboratively graded authentic answers of different standards. Finally, student grades were compared with those of faculty, differences considered, and key characteristics of answers were discussed. We also developed a model to engage students with the assessment and its role in BMS competency development. This demonstrated that assessment literate students were more confident in reading papers, analysing data, communicating their interpretation and in undertaking their exam. Surprisingly, we found our teaching also facilitated graduate attribute development. Students reported positive learning outcomes related to communication and personal and intellectual autonomy (not just research and enquiry). As a novel outcome of this work, we propose assessment literacy can successfully engage students with BMS developmental progression and enhance skills and dispositions beneficial to broader aspects of life after university.

## *Ethics statements*

### *Studies involving animal subjects*

Generated Statement: No animal studies are presented in this manuscript.

### *Studies involving human subjects*

Generated Statement: The studies involving humans were approved by Social Research Ethics Group (SREG), Deanery of Biomedical Sciences (sub-group of the Research Ethics Committee, School of Health in Social Science, University of Edinburgh).. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

### *Inclusion of identifiable human data*

Generated Statement: No potentially identifiable images or data are presented in this study.

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### *Data availability statement*

Generated Statement: The datasets presented in this article are not readily available because The datasets presented in this article are not readily available per ethics approval.. Requests to access the datasets should be directed to Kevin Robertson, [kevin.robertson@ed.ac.uk](mailto:kevin.robertson@ed.ac.uk).

In review

1 **Embedding assessment literacy can enhance graduate attribute development**  
2 **in a Biomedical Sciences curriculum**

3  
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20  
21  
22 **Key words:** assessment literacy, graduate attributes, biomedical sciences,  
23 feedback, peer assessment

24  
25 **Number of words: 7263**

26  
27 **Number of figures: 7**

28  
29 **Number of tables: 3**

30 **ABSTRACT**

31

32 This paper describes the successful implementation of an assessment literacy  
33 strategy within a Biomedical Sciences degree. Teaching was aligned with an  
34 assessment literacy framework and aimed to prepare undergraduates for a literature  
35 comprehension assessment. Students were introduced to the assessment purpose  
36 and an adapted Miller's pyramid model illustrated how the assessment contributed to  
37 competency development during their degree. Students read primary research  
38 papers and answered questions relating to the publications. They were then  
39 introduced to the processes of assessment and collaboratively graded answers of  
40 different standards. Finally, student and faculty grades were compared, differences  
41 considered, and key characteristics of answers discussed. Most students reported  
42 that they understood more about assessment standards than prior to the intervention  
43 (139/159 (87.4%)) and felt it had helped prepare them for their exam (138/159  
44 (86.8%)). The majority also reported they had increased confidence in evaluating  
45 data (118/ 159 (74%)), communicating their reasoning (113/159 (71%)) and  
46 considering what a reader needs to know (127/159 (79.9%)). Students were asked to  
47 state the most important thing they had learned from the assessment literacy  
48 teaching. Notably, no responses referred to domain-specific knowledge. 129 free text  
49 responses were mapped to the University of Edinburgh graduate attribute  
50 framework. 93 (72%) statements mapped to the graduate attribute category  
51 "Research and Enquiry", 66 (51.16%) mapped to "Communication" and 21 (16.27%)  
52 mapped to "Personal and Intellectual Autonomy". To explore any longer-term impact  
53 of the assessment literacy teaching, a focus group was held with students from the  
54 same cohort, 2 years after the original intervention. Themes from this part of the  
55 study included that teaching had provided insights into standards and expectations  
56 for the assessment and the benefits of domain specific knowledge. A variety of  
57 aspects related to graduate attributes were also identified. Here, assessment literacy  
58 as a vehicle for graduate attribute development was an unexpected outcome. We  
59 propose that by explicitly engaging students with purpose, process, standards, and  
60 expectations, assessment literacy strategies may be used to successfully raise  
61 awareness of developmental progression, and enhance skills, aptitudes, and  
62 dispositions beneficial to Biomedical Sciences academic achievement *and* life after  
63 university.

64 **INTRODUCTION**

65 Undergraduate Biomedical Sciences (BMS) degree programmes typically provide an  
66 interdisciplinary context in which learning about the science underpinning human  
67 health and disease is enabled (1). Importantly, alongside domain-specific learning, it  
68 is now widely accepted that higher education should prepare graduates for work and  
69 life after their formal studies (2). In this regard, BMS degrees are no different to any  
70 other. Over the past two decades, increasing numbers of fee-paying students, with  
71 broad career aspirations, and often significant debt, have created demand for the  
72 development of employability during a first degree (2, 3). BMS programme  
73 developers have responded to this in a variety of ways. Examples include the  
74 placement of students with employers, the delivery of employability workshops and/  
75 or an increased emphasis on integrating opportunities to enhance competency  
76 development and graduate attributes within curricula (4-6). Generic graduate  
77 attributes include, for example, competency in reflective practice, communication  
78 with diverse audiences, complex problem solving, assessing the performance of self  
79 and others, an inclusive and open attitude to engaging with others and intellectual  
80 autonomy (7, 8). A consequence of approaches targeted at integrating domain-  
81 specific and generic competencies can be curriculum complexity. This can make it  
82 challenging for students to navigate and understand their developmental  
83 progression.

84

85 Confidence in reading, analysing, interpreting, presenting, and using primary  
86 evidence to learn, develop hypotheses, solve problems, and enable decision-making  
87 (i.e., 'literature comprehension') is integral to all research practice. It is also a health  
88 and care professions council (HCPC) requirement for Biomedical Scientists and is  
89 key to many graduate careers (9). Competency in literature comprehension is,  
90 therefore, considered a core graduate attribute for all BMS graduates. At the  
91 University of Edinburgh (UoE), the BMS Literature Comprehension assessment  
92 (LCA) serves as an introduction for a diverse cohort of several hundred 2<sup>nd</sup> year  
93 undergraduates per year to the critical analysis of primary research. At this early  
94 stage, it is intended to facilitate the transition of students into their degree (and  
95 enhance inclusivity) by (a) clarifying expectations on how practising scientists  
96 analyse and use primary research material and (b) delivering a common  
97 understanding of standards and expectations prior to summative testing (10).

98

99 Since its inception in the early 2000s, the LCA has involved two formative tutorials  
100 and an open-book exam. Across the teaching and assessment, students analyse  
101 multiple primary research papers in-depth. By responding to short answer questions  
102 related to these papers, it is hoped participants can develop their approach to  
103 analysing primary evidence and communicating their own interpretations in a  
104 concise, logical manner. Before students attempt the summative assessment, they  
105 have extensive opportunities to develop their learning - key to both assessment *for*  
106 learning and inclusivity (10, 11). The literature comprehension assessment is not a  
107 test of memory, rather it presents an authentic challenge relevant to careers in BMS.  
108 In this regard, it serves to develop several attributes considered key by the Institute  
109 of Biomedical Science (IBMS). For example, questions require that students explain  
110 their rationale and use data to support conclusions. As such, the assessment  
111 establishes a foundation for biomedical competencies such as the communication of  
112 research findings using appropriate scientific language (1). End of course feedback  
113 from students has described the LCA as '*challenging yet rewarding*' and an



114 opportunity to *'feel like a scientist'*. Importantly, integrated within the domain-specific  
115 teaching of the LCA are also opportunities for students to develop (a) a general  
116 framework for thinking about evidence and (b) how they communicate to different  
117 audiences - both crucial to graduate attributes such as a capacity for critical/  
118 analytical thinking and ability to communicate in a variety of contexts (1).

119

120 Prior to 2019, the LCA was delivered at the UoE as shown in Figure 1A. At this time,  
121 a course review identified a range of issues related to teaching and assessment that  
122 needed to be addressed. These were (a) uncertainty in the student cohort regarding  
123 the purpose of the exercise (b) a tutor-focused teaching approach leading to  
124 inconsistent engagement of students in tutorials (c) inconsistent student  
125 communication of thinking and rationale in exams (d) inconsistent use of data/  
126 evidence to support answers in exams and (e) students regularly reporting that they  
127 felt, "*the exam was much harder than the tutorial exercises*". To address these  
128 issues, an intervention focused on assessment literacy was identified as a potential  
129 solution.

130

131 The concept and benefits of assessment literacy have been widely discussed (12-  
132 16). In this regard, a recent review has comprehensively defined a conceptualisation  
133 defining domains and dispositions required by students to engage with assessment  
134 in an effective manner (16). In brief, an assessment literate individual has the  
135 knowledge, attributes, and skills to 'actively engage in assessment, monitor their  
136 learning, engage in reflective practice, and develop effective skills, to improve their  
137 learning and performance outcomes' (Figure 2) (16). Further, they will understand  
138 how assessments contribute to learning and progression, how assessments are  
139 undertaken and can use criteria for self or peer assessment. Given this  
140 understanding, an assessment literate student will be able to use an appropriate,  
141 relevant method for any given assessment task (13). Crucially, an absence of  
142 assessment literacy can impede an individual's capacity to learn and, if assessment  
143 literacy is not promoted, it can limit inclusivity, equity and participation in higher  
144 education (15).

145

146 In 2015, an assessment literacy intervention was used to enhance veterinary  
147 undergraduate teaching at the UoE (13). In this intervention, the use of Miller's  
148 pyramid helped promote a common understanding (in teachers *and* students) of  
149 curriculum progression and, importantly, how a given specific assessment functioned  
150 within the curriculum. Miller's pyramid has been widely used as a model for  
151 assessing levels of clinical competence (17, 18). In the pyramid, cognitive levels  
152 'knowledge' ('Knows') and 'application of knowledge' ('Knows how') function as a  
153 foundation for a subsequent 'practical application of knowledge' ('Shows how') which  
154 in turn supports 'Does' - representing (graduate) practitioner competence. Notably,  
155 the 2015 intervention required that students evaluate authentic work of differing  
156 quality and discuss attributes that are valued by learners and staff. This resulted in a  
157 better understanding of standards, and helped students prepare for a subsequent  
158 assessment (13, 18). Given the success of this assessment literacy intervention, a  
159 novel Assessment Literacy Pyramid (ALP) designed to support student assessment  
160 of their own and peer performance at all levels of a developmental programme has  
161 subsequently been developed (18).

162

163 The primary aim of this study was to evaluate assessment literacy as a unifying  
164 concept and practical approach to enhance literature comprehension in the context  
165 of a BMS curriculum. Specifically, the objective was to explore whether assessment  
166 literacy could; clarify for students why an assessment was being used, clarify  
167 expectations regarding assessment criteria, answer questions, address past  
168 criticisms, improve engagement in, and inclusivity of, teaching sessions, enhance  
169 student capacity for self-evaluation and, ultimately, make the assessment less  
170 intimidating. As part of this work, we aimed to develop a BMS competency pyramid  
171 to enhance communication of curriculum opportunities and progression to our  
172 students.

In review

## 173 **METHODS**

### 174 **Teaching Context**

175 This study was undertaken with students in the 2<sup>nd</sup> year (Scottish Credit and  
176 Qualifications Framework Level 8) of a 4-year non IBMS accredited BMS degree  
177 programme. The literature comprehension assessment was a component of a single  
178 semester compulsory course focused on the fundamentals of infection and immunity  
179 (Learning outcomes presented in Supplementary Table S1). Students were required  
180 to pass all components (exam, essay, and literature comprehension assessment) of  
181 the course to progress to the next academic year. As per standard UoE practice, a  
182 range of adjustments were provided to students according to individualised profiles  
183 developed by the student and the university Disability and Learning Support Service  
184 (DLSS). Adjustments included, for example, extra time for submission of the  
185 assessment and the provision of time for students to use proof-reading services.  
186 Additionally, for use with screen readers and to enable reformatting, accessible  
187 versions of primary research papers (converted to plain HTML, with ALT tag  
188 descriptions of data and validated by staff in the DLSS) were available.

189  
190 Prior to and including 2018, teaching related to the literature comprehension  
191 assessment was as shown in Figure 1A. In brief, all students read three papers (one  
192 per week over a three-week period) prior to undertaking their assessment. After  
193 reading review paper 1, students answered online multiple-choice questions related  
194 to the scientific detail of the study. For papers 2 and 3, students read the primary  
195 research publications and then answered short-answer questions related to the  
196 paper. They then attended tutor-driven teaching sessions in which staff led students  
197 through the paper, and students were invited to discuss and report back on their  
198 answers. Students were provided with a primary research paper one week before  
199 their exam. For the 90-minute exam, students were permitted to use an annotated  
200 copy of the paper to help them answer 12 to 14 short answer questions of a similar  
201 style to those they had previously encountered in the formative work.

202

### 203 **Assessment literacy intervention**

204 To test whether an assessment literacy-based teaching approach could address the  
205 issues encountered prior to 2019 (detailed in the introduction), a phased assessment  
206 literacy intervention was designed based on previous work (13). The development of  
207 this intervention is presented in Figures 1B and 1C.

208

#### 209 **Phase 1 of intervention (2019)**

210 In phase 1 of the intervention (Figure 1B), Review paper 1 and the associated MCQ  
211 were replaced with a brief pre-recorded presentation (available in supplementary  
212 information) designed to introduce the purpose of the assessment and address  
213 questions often asked about the teaching material. Notably, as part of this  
214 intervention, a BMS competency pyramid (based on Miller's pyramid) was developed  
215 to help convey and define the function of the assessment in the BMS curriculum. In  
216 recent years, Miller's pyramid (and adaptations of the model) have been successfully  
217 used as an integral component of assessment literacy interventions (13, 18). In this  
218 context, it can show students (a) where they are in their competency development  
219 and (b) what function the assessment literacy intervention will play in their  
220 development of new competencies. It was hoped the BMS competency pyramid  
221 would serve as a useful tool for representing the bridge between academic degree

222 learning and graduate practice. To build a pyramid model with a BMS focus, two  
223 main resources were used to identify desirable competencies for each level. Firstly,  
224 the UoE degree finder was used to define year-on-year development of BMS  
225 knowledge, skills and attributes. Alongside this, desirable competencies drawn from  
226 the Subject Benchmark Statement for BMS were also integrated into the pyramid  
227 model at all levels (19). Figure S1 illustrates how early stages of the BMS model  
228 evolved from Miller's pyramid to the integration of a preliminary subset of attributes  
229 and competencies broadly related to literature comprehension. The current BMS  
230 competency pyramid is presented in Figure 3.

231  
232 The first tutor-led teaching session was also adjusted in phase 1 (2019) of our  
233 assessment literacy intervention (Figure 1B). In the new tutorial, students were  
234 introduced to the processes of assessment and the benefits of the assessment to  
235 competency development were discussed. Most importantly, students then worked  
236 together to grade authentic answers of different standards from previous years. To  
237 conclude, student grades were collated and compared with those of faculty and  
238 exemplar answers were analysed and discussed to identify characteristics that were  
239 rewarded during the marking process. A representative example of a question,  
240 analysis of student responses and marking criteria are presented in the  
241 supplementary information (Figure S2). Following the 2019 pilot intervention,  
242 feedback on revised teaching was gathered as part of the standard deanery-wide  
243 end of course survey. In this survey, all students were invited to complete an  
244 electronic feedback form that included eight tutorial-focused Likert scale questions  
245 and a free text question in which respondents were asked to provide comments on  
246 the tutorial teaching and associated assessment (Supplementary Table S2).

### 247 248 **Phase 2 of intervention (2020)**

249 In 2020, all LCA teaching was migrated to the assessment literacy-based approach  
250 (Figure 1C). All students were provided with an introductory presentation followed by  
251 two tutorials in which they graded authentic answers using a marking scheme,  
252 compared marks with those of faculty and discussed desirable features of an answer  
253 (as described above). To analyse the effects of our 2020 teaching (completed before  
254 disruption due to the COVID pandemic), a short paper-based survey was distributed  
255 to 186 students at the conclusion of tutorial 2. This questionnaire was intended to  
256 explore student expectations and understanding of assessment and whether  
257 students felt prepared for the literature comprehension test. Notably, this survey was  
258 also used to analyse student opinions on the importance of graduate attribute  
259 development and their awareness of how and when they are developing graduate  
260 attributes. Survey questions are presented in Tables 1 and 2. Students were  
261 presented with 12 statements about assessment or graduate attributes and asked to  
262 indicate their level of agreement with these statements on a 5-point Likert scale from  
263 strongly disagree to strongly agree. Responses to 2 free text questions were also  
264 captured. Free text questions asked students to (a) "give examples of graduate  
265 attributes you think you have already developed as part of your studies at the  
266 University of Edinburgh?" and (b) "state the most important thing you learned from  
267 the literature comprehension tutorials".

### 268 269 **Assessment Literacy intervention: data collection, processing, and** 270 **analysis** 271 **Student and faculty grading data**

272 Grades awarded by students to each of five questions were recorded in eight  
273 tutorials undertaken in 2020. To explore the accuracy of student grading in relation to  
274 the faculty grade, student bias was calculated as an average of the difference  
275 between each student grade and the recorded faculty grade for each question. The  
276 percentage bias as a function of the actual grade for each question was then  
277 calculated. This provides a measure of how the mean of the student grades relates  
278 to the faculty grade. The root mean square error (RMSE) was also calculated to  
279 reflect the variation of student grades around the faculty grade (i.e., it provides a  
280 descriptive evaluation of the differences between the faculty grade and the student  
281 grades).

### 282 **Assessment literacy questionnaire data processing and analysis**

284 Likert scale data from 159/186 questionnaires returned (85% response rate) in 2020  
285 were compiled and, for each question, the total number of responses for each of the  
286 5 options (strongly disagree (SD), disagree (D), no strong feelings (NSF), agree (A)  
287 or strongly agree (SA)) was calculated and tabulated.

### 288 **Analysis of free text responses to graduate attribute development and learning**

289 Free text responses to the questions (a) “give examples of graduate attributes you  
290 think you have already developed as part of your studies at the University of  
291 Edinburgh?” and (b) “state the most important thing you learned from the literature  
292 comprehension tutorials” were mapped to UoE graduate attributes (19). In brief, 115  
293 free text responses to the question “Can you give examples of graduate attributes  
294 you think you have already developed as part of your studies at the University of  
295 Edinburgh?” were compiled. Each of the responses was then classified according to  
296 whether they represented ‘Mindset’ and/ or a ‘Skill Group’ as defined in the UoE  
297 framework for graduate attributes (summarised in Supplementary Figure S3) (19).  
298 Where possible, each response was further classified according to one or more sub  
299 skill groups (e.g., “Research and Enquiry [Analytical Thinking]). Classifications were  
300 not mutually exclusive, and one statement could be assigned several headings.  
301 During this process, 18 responses were excluded from further analysis where the  
302 meaning of the written response was unclear/ ambiguous (Supplementary Table S3).

303  
304  
305 129 free text responses to the question “state the most important thing you learned  
306 from the literature comprehension tutorials” were analysed in an identical manner to  
307 that described above. During this process, 13 responses were excluded from further  
308 analysis where the meaning of the written response was unclear/ ambiguous  
309 (Supplementary Table S4).

### 310 **Focus group analysis of long-term intervention impact**

311 In 2022, to explore the long-term impact of the 2020 assessment literacy teaching,  
312 final year students who had experienced the intervention (n=186) were sent an open  
313 invitation by email to contribute to a focus group. Four students responded to the  
314 invitation. Having read a further information form and provided their written consent,  
315 the 4 students attended an online focus group lasting roughly 1 hour. The focus  
316 group was facilitated by a UoE academic with no BMS teaching involvement who  
317 sought to gather student feedback on (amongst other aspects) recollections of the  
318 LCA purpose, opinions on how it helped their ability to use primary papers, how  
319 teaching helped understanding of assessment process and the broader impacts of  
320 the teaching. Focus group questions are presented in Table 3.  
321

322

323 **Integration of Graduate Attributes into Biomedical Competency**  
324 **Pyramid**

325 Having used the BMS competency pyramid (Figure 3) as part of the assessment  
326 literacy intervention described here, we sought to develop this aspect further and  
327 integrate graduate attributes into a pyramid model. For this, the UoE Graduate  
328 Attribute Mindsets and Skills framework (<https://www.ed.ac.uk/graduate-attributes>)  
329 and Subject Benchmark Statement for BMS were used as a reference. The graduate  
330 attribute pyramid generated during this study is presented in Figure 4.

331

332 **Ethical approval for study**

333 Ethical approval for both the survey and focus group were obtained from the Social  
334 Research Ethics Group (SREG), Deanery of Biomedical Sciences (sub-group of the  
335 Research Ethics Committee, School of Health in Social Science, University of  
336 Edinburgh).

In review

## 337 **RESULTS**

### 338 **Students tend to award lower grades than faculty**

339 In eight separate literature comprehension tutorial 2 sessions undertaken in 2020,  
340 student grades were recorded for 5 questions (12 answers in total). Histograms  
341 derived from this data (Figure 5) show variations in the distribution of marks awarded  
342 by students for each question. A dotted line indicates the mean mark awarded for the  
343 question by two independent faculty markers. Percentage bias for each question is  
344 indicated and shows that for 10 out of the 12 answers, students returned lower  
345 marks than faculty members. The maximum percentage bias was -30% highlighting  
346 that most students had awarded a lower grade than faculty for this question (Q1A2).

### 348 **Positive impact of assessment literacy intervention on student confidence in 349 literature comprehension assessment**

350 In 2020, having migrated all teaching of the formative literature comprehension  
351 tutorials to an assessment literacy format, our next step was to explore student  
352 understanding of their assessment to-date, find out if they were positive about the  
353 changes we had implemented and, ultimately, discover if they felt more confident  
354 about their upcoming assessment. To achieve this, at the conclusion of the final  
355 preparatory tutorials, 186 students across the eight tutorial groups were asked to  
356 complete Likert scale questions related to how prepared they felt for their  
357 assessment. 159 questionnaires were returned, and the data is presented in Table 1.  
358 In brief, students broadly agreed that they had a good understanding of how their  
359 assessments were marked (111/159 agreed or strongly agreed) and indicated they  
360 consider this an important aspect of their learning. Notably, students indicated the  
361 assessment literacy intervention had helped them understand more about different  
362 assessment standards (139/ 159 (87.4%) indicated they agreed or strongly agreed).  
363 Related to this, most students agreed or strongly agreed that the tutorials had helped  
364 them prepare for their exam (138/159 (86.8%)) and made them feel more confident  
365 about communicating their own interpretations and reasoning related to primary  
366 research papers (113/159 (71.1%)). Importantly, 127/159 (79.9%) students indicated  
367 that they agreed or strongly agreed that the teaching had made them consider what  
368 a reader needs to know. Further, 118/ 159 (74.2%) students agreed or strongly  
369 agreed that the tutorials had helped them evaluate and use data to support their  
370 answers to questions. The broadly positive response we received via the targeted  
371 tutorial questionnaire was supported and reinforced by later free text comments  
372 gathered in the standard Deanery end of course survey (2020):

373  
374 *“I liked the way they were structured. We got to have a practise on our own before  
375 the live tutorial. Marking previous answers definitely helped me in understanding how  
376 to approach my own answers.”*

377  
378 *“It was really nice to learn more about the marking schemes, which helped me better  
379 understand the learning outcomes for the assignment and in general the quality and  
380 kinds of specific details markers look for in good answers. I was also able to apply  
381 the skills I learned in the tutorial sessions to similar assignments in other courses”*

382  
383 *“I liked the tutorials as it gave an opportunity to consolidate learning. They also gave  
384 an idea of what the Literature Comprehension Assessment would be like, which I  
385 found beneficial to help remove any anxiety I had about the assessment.”*

386

### 387 **Students are aware of graduate attributes and value their development**

388 During phase 1 (2019) delivery of our new tutorials, discussions with students as part  
389 of our teaching indicated that our assessment literacy approach had not just helped  
390 support their engagement with infection-related primary research, it may also have  
391 helped facilitate the development of graduate attributes. Amongst other aspects,  
392 grading answers of different standards focused students on the logic of their  
393 analytical approach, on how they communicated, and encouraged them to reflect on  
394 their own work and exercise critical judgement. Given this observation, in 2020 we  
395 sought to find out more about student comprehension of graduate attributes and to  
396 explore student perceptions of what they had learned from the tutorials. To achieve  
397 this, as part of the 2020 end-of-tutorial questionnaire, we integrated several graduate  
398 attribute-related questions. To begin, we asked students if they had heard of  
399 graduate attributes. Of those who responded (135/159), most (97/ 135) replied 'yes',  
400 whilst 38 had not heard of this term. To follow this up, using Likert scale questions  
401 we proceeded to ask students if they valued the development of graduate attributes  
402 and if they know when they are developing graduate attributes as part of their  
403 degree. Responses to these questions showed students consider the development  
404 of graduate attributes a very important aspect of their degree (147/ 159 (92.5%)  
405 agreeing or strongly agreeing). Notably, 97/159 (61%) of students felt they knew  
406 when they were developing graduate attributes as part of their normal degree work  
407 with less than 1% unsure when graduate attribute development is occurring.  
408

409 To explore student perceptions of graduate attributes further, we proceeded to ask  
410 students if they could provide examples (in free text) of graduate attributes they had  
411 developed to-date in their degree. 115 answers were returned in response to this  
412 question. Responses were variable and ranged from "*How to write a lab report*" to  
413 "*Questioning and analysis of myself and the world around me*". To help us  
414 systematically analyse the data, responses were mapped to the UoE graduate  
415 attribute framework (19). Following this mapping, to identify themes, classifications of  
416 identical type were grouped and quantitated. The results of this analysis are  
417 presented in Figure 6. It is important to note that a small number of responses from  
418 students referred to specific degree and/ or biomedical domain-related skills that  
419 would not typically be defined as graduate attributes. To reduce selection bias, and  
420 develop a representative view of the student cohort, the majority of these were  
421 retained in our analysis unless meaning was unrelated or ambiguous (e.g., 'tutorial  
422 skills'). See Supplementary Table S3 for statements excluded from the analysis.  
423

424 The most notable theme emerging from the student responses was that they  
425 identified "Research and Enquiry" as the main area of graduate attribute  
426 development in years 1 and 2 of their study (Figure 6A). Under this classification,  
427 sub-skills that emerged included "critical thinking", "analytical thinking", "knowledge  
428 integration and application" and "problem solving". After "Research and Enquiry", the  
429 remaining skill groups (e.g., "Communication", "Personal and Intellectual Autonomy"  
430 or "Personal effectiveness") had a similar representation in the data (Figure 6B).  
431 Importantly, year 2 BMS students referred to very few attributes that could be  
432 classified as related to a "Mindset" as defined in the UoE graduate attribute  
433 framework (Figure 6C) (19). Where a "Mindset" could be applied to a proposed  
434 attribute, the most common classification was "Enquiry and Lifelong Learning".  
435 Examples of student statements falling under this classification included "Confidence  
436 of how to learn from mistakes", "Being critical of my own work as well as others" and



437 “Ability to take responsibility for my own learning”. Notably attributes that could be  
438 classified as “Outlook and engagement” (2 statements) (“Understanding the  
439 relevance of work and its effect on future research” and “Self-motivation”) or  
440 “Aspiration and personal development” (1 statement) (“Insight into the qualifications  
441 and experience needed to go into a career in academia or research”) were sparsely  
442 represented in the data.

443  
444 Given our earlier observation (2019) that students in our assessment literacy  
445 tutorials were focussing much of their discussion, questions and learning on the  
446 development of broad skills related to graduate attributes, we used our 2020  
447 questionnaire to ask students to state the most important thing they had learned from  
448 our teaching. 129 responses to this question were mapped to the UoE graduate  
449 attribute framework and themes identified as above (Figure 7). As before, to reduce  
450 selection bias, and develop a representative view of the student cohort, the majority  
451 of these were retained in our analysis unless meaning was unrelated or ambiguous.  
452 See Supplementary Table S4 for statements excluded from the analysis.

453  
454 Notably, no student responses stated the most important thing they had learned was  
455 a specific aspect of the infection-related biology covered in our papers. Almost all  
456 responses could be mapped to the graduate attribute framework with a small number  
457 excluded from our analysis (e.g., “The kind of questions expected in the exam”).  
458 Once again, most student responses (93 (72%) statements classified into this  
459 category) could be classified as related to “Research and Enquiry”. Examples of  
460 statements grouped into this category include “How to take more from a research  
461 paper - understand figures and data and analyse them” and “How to pick out  
462 important information and which pieces of data are required to draw meaningful  
463 conclusions.”. Alongside “Research and Enquiry”, “Communication” was a clear  
464 theme evident in the data (66 statements (51%) classified into this category). In this  
465 regard, statements such as “To answer questions with adequate detail and to refer to  
466 data and figures in my answers” and “How to communicate elements of a scientific  
467 paper to others” were classified into this category.

468  
469 Notably, a clear theme emerging from the statements on important learning  
470 outcomes related to “Personal and intellectual autonomy” (21 statements (16.27%)  
471 were classified into this category). Specifically, a range of statements indicating  
472 enhanced confidence in independent learning and exercising judgement. These  
473 included “It was really useful to see an actual mark scheme - gives me a better idea  
474 of what you look for” and “How to approach a question because we got to see the  
475 marking scheme which made it clearer to me to what the markers are looking for.”

476  
477 **Long-term benefits of assessment literacy literature comprehension teaching**  
478 The data described above were gathered at the time of (or shortly after) the tutorials  
479 and assessment were undertaken. Given the intended function of this teaching is in  
480 the development of foundational skills supporting later development (‘Knows’ and  
481 ‘Knows how’) we wanted to explore how final year students felt this work had  
482 influenced their later learning. To achieve this, all 4<sup>th</sup> year students who had  
483 undertaken and completed assessment literacy tutorials (before COVID disruption) in  
484 2<sup>nd</sup> year (n=186) were invited to contribute to a focus group and four students agreed  
485 to participate. When asked what they remembered about the tutorial purpose,  
486 student recall of the teaching was variable, however, 3 out of the 4 participants

487 responded with answers that indicated they felt the teaching had been beneficial. For  
488 example:

489  
490 Participant 3:

491 *[in the past] "I was confident with like understanding what the point of the*  
492 *paper was. Just from, you know, abstract and conclusion mainly, but what I*  
493 *found difficult is understanding like how exactly the method was, what exactly*  
494 *did they use this marker for or what was the point of that enzyme. I remember*  
495 *them asking into like very very details of the methods. Which I found quite*  
496 *difficult, but I think it was beneficial 'cause then we actually were forced to*  
497 *learn, to understand how they made up the experiment or how to connect the*  
498 *dots a bit better."*

499  
500 To develop the discussion, students were then asked if the teaching influenced their  
501 understanding of the assessment process. A key theme from answers to this was  
502 that students felt the teaching did provide insight into expectations for the  
503 assessment. For example:

504  
505 Participant 1:

506 *"...the tutorial questions were really quite difficult from what we remember...*  
507 *and it did probably show you how much detail they were expecting... yeah,*  
508 *the tutorials definitely showed you how much in depth they were wanting."*

509  
510 When asked to consider whether the literature focused tutorials were undertaken at  
511 the correct time in their degree, students responded positively. For example:

512  
513 Participant 1:

514 *"I think going in that much depth it was probably the right time... I think if*  
515 *someone had said to me in first year, here's some questions on these papers,*  
516 *I would have internally exploded. But at the same time something along those*  
517 *lines, but maybe a bit more basic might have been handy in first year... I think*  
518 *yes, end of second year is probably about right."*

519  
520 To explore the long-term impact of the teaching, participants were then asked if they  
521 thought the tutorials and paper analysis had helped in later years of their degree.  
522 Notably, responses to this question were variable and context dependent. One  
523 response indicated they felt the teaching had been broadly beneficial, whilst another  
524 indicated it was directly relevant to their current work.

525  
526 Participant 3:

527 *"I think probably unconsciously. I don't think I would particularly think back to*  
528 *the tutorials and think that definitely helped me in what I'm doing now, but I*  
529 *think it was just one of those skills you pick up along the way and you don't*  
530 *even realize that you've got it until now you can do it fine."*

531  
532 Participant 2:

533 *"...my project is a systematic review of technologies... it's definitely very, very*  
534 *literature understanding based...so for mine it definitely applies"*

535

536 Finally, having questioned the students on their recollections of the tutorials and their  
537 impressions of the benefits, the group were asked 'what sorts of things that you've  
538 picked up along the way during your degree and that you're doing now in your work  
539 [studies] will you be able to apply in whatever you want to do in the future?' Answers  
540 were varied but included mention of the benefits of domain specific knowledge as  
541 well as a variety of aspects related to graduate attributes (e.g., time-management,  
542 communication to varied audiences and a propensity to be more inquisitive).

543  
544 Participant 3:

545 *"I would say that the degree has made me more inquisitive, so I'm more likely*  
546 *to wonder about things and then want to go and find out more."*

547  
548 Participant 1:

549 *"I would say I think it's very general as well, but definitely from our experience,*  
550 *just general like essay writing and like writing skills."*

551  
552 Participant 2:

553 *[Comfortable with] "A multidisciplinary approach".*

In review

554 **DISCUSSION**

555 In the work described here, we have successfully transitioned an assessment  
556 literacy strategy from a vocational veterinary teaching context to a foundational BMS  
557 learning activity (13, 18). As an outcome of this, learning became student-focused  
558 and engagement in tutorials was enhanced. Importantly, students reported greater  
559 confidence in their understanding of how marks were awarded, the features of a  
560 good answer and in preparing for their assessment. An unexpected yet welcome  
561 outcome of this approach was that our assessment literacy-based teaching  
562 functioned as a vehicle for graduate attribute development within a domain-specific  
563 activity. The implications of this observation to our BMS teaching will be discussed  
564 further here.

565  
566 The past 20 years has seen a sometimes-controversial shift in the focus of higher  
567 education teaching (20). Over this period, universities have seen their remit widened  
568 and it is now accepted they must develop not just discipline-specific graduates but  
569 also provide a general foundation for graduate attributes that enhance employability  
570 (21, 22). This presents several challenges. As Green *et al.* point out, graduate  
571 attributes have proven difficult to define and are perceived in a variety of ways by  
572 academics (21). As a result, constructive communication between academics, and  
573 between academics and students, regarding graduate attribute development has  
574 been hard to achieve (21). Like many higher education institutions, the UoE has  
575 published a graduate attribute statement that serves to establish the generic skills  
576 and dispositions students can develop during their degree (19). A key question is  
577 how can the development of graduate attributes be integrated into existing curricula  
578 and disciplinary contexts? One response to this has been curriculum mapping –  
579 most commonly undertaken for degrees integrating some form of professional  
580 accreditation or recognition (e.g., HCPC approved degree programme mapping to  
581 Standards of Proficiency for Biomedical Scientists) (9, 23). Curriculum mapping can  
582 be useful in identifying existing graduate attribute development activities that are not  
583 addressed in, for example, learning objectives. It can also identify requirements,  
584 opportunities, and potential linkages between years in the curriculum. Importantly,  
585 once mapping is complete, a key question is how can the teaching and learning  
586 environment be adjusted to focus students on the development of graduate attributes  
587 in their domain? Notably, whilst assessments can serve to motivate students to  
588 engage in learning, recent data suggests the explicit assessment of graduate  
589 attributes may be unpopular with students (24). Focus group analyses revealed  
590 students did not think assessment of graduate attributes would serve as an  
591 incentive for engagement (24). Further, some students felt assessment would  
592 engender an increased emphasis on marks and may prove to function as a personal  
593 affront (24).

594  
595 At the outset of this study, we aimed to adopt an assessment literacy approach to  
596 help students learn how to read, analyse, and communicate their interpretations of  
597 primary research papers. On completion of our teaching, feedback from students  
598 indicated this strategy moved our teaching away from a teacher- and domain-centric  
599 approach and enhanced student confidence and competence in both the process of  
600 assessment and literature analysis. In agreement with previous studies, the data  
601 presented here show notable variation in the ability of students to accurately grade  
602 work. In contrast to previous work, however, where over or under grading was not  
603 consistent, in this study students tended to award lower grades than faculty (13).

604 Exploration of this finding, by further discussion of grade differences with students in  
605 tutorials, revealed a key disparity between faculty and student perspective. Students  
606 often demonstrate a focus on the concept of losing marks and the presence of a  
607 final, definitive conclusion as a key requirement for mark reward. To address the  
608 above required that we consider the students 'metacognitive' development – how  
609 could we facilitate the development of a marker's perspective in students? We now  
610 ensure our approach emphasises that faculty adopt a 'positive marking' philosophy –  
611 rewarding rather than taking away. We also emphasise the importance of  
612 considering the audience, the value of contextual information, and that marks are  
613 accumulated through the development of clearly communicated, systematic  
614 answers. Students are encouraged to reflect on the needs of the audience and  
615 answer questions such as: what was the authors question? What did the authors do?  
616 What does the data show? What interpretations and conclusions can be drawn?  
617 What do I need to communicate? By providing this process for developing their  
618 responses, and engaging students in marking answers following the same logic, the  
619 assessment literacy approach can help students focus on how to analyse and  
620 develop an answer.

621  
622 At the conclusion of our 2020 teaching, in contrast to previous years, no student  
623 feedback relating to the year of publication of the primary research papers and the  
624 relationship between tutorials and lectures was received. We ascribe this to the  
625 inclusion of an introductory presentation used to explain the aim of the teaching/  
626 assessment and the assessment literacy approach. Notably, students did, however,  
627 report enhanced confidence in, and the development of, skills and attributes beyond  
628 the domain-specific area (infectious diseases). These attributes could be classified  
629 according to the UoE graduate attribute framework as enhanced skills in research  
630 and enquiry, communication and, importantly, independent learning and exercising  
631 personal judgement (19). By engaging students with standards and expectations,  
632 evidence to-date, therefore, suggests assessment literacy can facilitate the  
633 engagement with, and development of, graduate attributes.

634  
635 As an integral part of this work, Miller's pyramid was adapted to show BMS  
636 competency development from degree entry to practitioner (18). This helped us  
637 communicate to students where their literature comprehension teaching and  
638 assessment fitted into overall BMS competency development. In doing so, it helped  
639 us address the need for a 'transparent' curriculum and provide students with the  
640 opportunity to work towards 'declared' objectives and plan for future skill  
641 development (25). Overall, we view this representation as dynamic and envisage it  
642 will evolve over time as we receive input from colleagues and other stakeholders  
643 (see limitations below). Importantly, to extend this work the pyramid approach  
644 facilitated the systematic mapping of UoE graduate attributes to BMS competency  
645 development - allowing us to conceptualise graduate attributes in a specific domain  
646 context (Figure 4). A future objective is to test how this helps us to convey to the  
647 students how graduate attribute development can evolve over the degree and what  
648 can be expected at different levels.

649  
650 Importantly, the development and use of the BMS competency pyramid highlighted  
651 several key issues. The work described here indicates a requirement for a  
652 systematic analysis of our entire BMS curriculum with the aim of identifying  
653 requirements and opportunities for graduate attribute development and assessment

654 embedded within or alongside current teaching, learning and assessment activities.  
655 In this regard, our work agrees with recent findings showing limited evidence for  
656 specific educational approaches driving the systematic development of graduate  
657 attributes in UK undergraduate degrees (26). Several models for curriculum and  
658 graduate attribute mapping exist and the activity will have to complement or be part  
659 of an ongoing curriculum transformation programme at the UoE (22, 23, 27, 28).  
660 Given our data emphasising the importance students place on graduate attribute  
661 development, it would seem prudent that this process is undertaken in partnership  
662 with students (29).

663  
664 Use of the competency pyramid and parallel analysis of student questionnaire  
665 responses emphasised a focus on student attribute development related to  
666 Research and Enquiry in years 1 and 2 of the BMS degree. This was expected given  
667 an early teaching focus on formative activities enabling academic competency and a  
668 transition to university. Importantly, analysis of year 2 student questionnaire data  
669 revealed a focus on graduate attributes defined as 'skills' by the UoE graduate  
670 attribute framework (19). These data, and the variable responses we obtained  
671 regarding the long-term impact of competency and graduate attribute development in  
672 our focus group, highlight an opportunity for use of assessment literacy throughout  
673 our curriculum. As a next step, we plan to explore the use of assessment literacy and  
674 regular engagement with the competency/ graduate attribute pyramid model in all  
675 years to help students acknowledge and reflect on their development. In doing so,  
676 they may recognise when changes in, for example, their outlook or mindset occur as  
677 they progress through the degree. In this regard, it was notable that in our focus  
678 group, one student did remark that they were more 'inquisitive' at the conclusion of  
679 their studies. Evidence on undergraduate mindset development is limited and studies  
680 that have emerged suggest undergraduates do not change mindset over time (30).  
681 Of some concern, are studies that indicate STEM students develop an increasingly  
682 fixed mindset as they progress through their studies (31). A key future objective for  
683 our work, therefore, is to explore how we can use assessment literacy and our  
684 competency/ graduate attribute model throughout the curriculum to help students set  
685 and importantly achieve objectives that demonstrate development and promote  
686 "growth" mindsets enabling them to take on challenges and achieve success (30).  
687 Notably, a recent study described peer interaction – integral to our assessment  
688 literacy approach – as influential in determining student mindsets (30). Whilst it was  
689 not a focus of the work described here, involving students in discussion of  
690 assessment, and reflecting on how it has impacted their development, could also be  
691 useful as a means of gathering valuable additional insight into their perspective as  
692 partners in the assessment process; in particular in relation to key aspects such as  
693 inclusivity and the impact assessment has on student wellbeing (32, 33).

694  
695 To conclude, as several authors have noted, graduate attributes are not generic and  
696 their definition, and how they are perceived, differs between disciplines (21, 34, 35).  
697 To address this, it has been proposed that teaching processes make it clear how  
698 aspects of a degree (including assessments) contribute to graduate attribute  
699 development. This will help students recognise how their study might prepare them  
700 for later work (26). Models developed to enhance assessment literacy may help to  
701 achieve this by engaging students with process, purpose, application of standards  
702 and expectations. In doing so, they may be used to enhance skills, aptitudes and  
703 dispositions enabling parallel academic achievement and transition to the workplace.

704

## 705 **Limitations**

706 There are several limitations to consider when interpreting these data and drawing  
707 conclusions. Firstly, the data gathered here was from a single course, at a single  
708 institution. Whilst the UoE BMS student cohort is typically drawn from a diverse  
709 range of cultural and educational backgrounds, we cannot predict that the findings  
710 will be generalisable to other contexts. The study could be strengthened by  
711 replication with a more representative sample of undergraduates.

712

713 In relation to the study design, a clear limitation relates to the size and composition  
714 of our focus group. Students volunteered to participate in this exercise and,  
715 therefore, represent a very limited portion of potential respondents. In both the  
716 questionnaires and the focus group, we have captured self-reported responses to  
717 our teaching. Additionally, in the case of the focus groups, students reported  
718 retrospectively. As a result, our data are prone to recall bias and other cognitive  
719 biases and may not be representative of the wider student population.

720

721 In the comparison of the student and faculty grades, two members of faculty had  
722 originally marked the answers analysed in the tutorials. As such, it was not possible  
723 to apply statistical testing to enhance the validity of our conclusions in this regard.  
724 The study could be strengthened by the addition of further faculty markers. Not only  
725 would this strengthen the statistical analysis, but we also anticipate a wider faculty  
726 contribution would generate valuable discourse re. what is, and should be, rewarded  
727 in an assessment.

728

729 At the outset of this project, a key aim was to evaluate the year-on-year effect of the  
730 assessment literacy intervention on overall class grades. Ultimately, this was not  
731 possible due to changes in delivery of the assessment in response to the COVID  
732 pandemic. In 2020, the exam moved from a 90-minute invigilated format to an online  
733 assessment undertaken over a 24h period. For both academic and practical reasons,  
734 this online delivery method has been retained and, with no like-for-like comparison  
735 possible, we have not sought to directly test whether our intervention had a positive  
736 effect on cohort grades. Further studies to directly test the impact of assessment  
737 literacy intervention are required, however, the similarity of adjacent cohorts cannot  
738 be assumed.

739

740 In relation to our data analysis, a methodological limitation relates to the mapping of  
741 respondent data to the graduate attribute framework. Every effort was made to  
742 undertake this in a systematic manner and response classifications were agreed  
743 between authors. Notably, however, an absence of, for example, a controlled  
744 vocabulary means this aspect of the study may be subject to bias.

745

746 The work described here was undertaken using existing definitions of graduate  
747 attributes as defined in the UoE graduate attribute framework and described in the  
748 literature. This may be considered a limitation, and future studies would benefit from  
749 more active dialog with employers with the aim of defining specific competencies and  
750 attributes considered desirable in the graduate workplace. This input would be  
751 valuable to future curriculum development.

752 **Summary Table**

753

754 **What is known about this subject:**

- 755
- Biomedical Sciences degrees must provide domain specific learning and prepare
- 756 graduates for work and life after their studies.
- 757
- Assessment literacy based teaching enables students to use an appropriate, relevant
- 758 method for any given assessment task.
- 759
- An absence of assessment literacy can impede an individual's capacity to learn and
- 760 can limit inclusivity, equity, and participation in higher education.

761

762 **What this paper adds:**

- 763
- Assessment literacy teaching enhanced student engagement in tutorials.
- 764
- Assessment literacy teaching improved confidence in student understanding of
- 765 standards and in preparation for an assessment.
- 766
- Assessment literacy teaching also facilitated graduate attribute development within
- 767 a domain-specific activity.

768

769 **Concluding Statement:**

770 This work represents an advance in biomedical science because it shows that

771 assessment literacy teaching in a BMS degree may be used to enhance skills,

772 aptitudes and dispositions enabling parallel academic achievement and transition to

773 the workplace.



**Figure 1. Delivery of literature comprehension teaching before and after the assessment literacy intervention. (A)** Literature comprehension teaching prior to the assessment literacy intervention. Students engaged with scientific material in Review paper 1 by reading the publication and answering online multiple-choice questions focused on the scientific content of the review. Students then participated in two teacher-led tutorials intended to prepare them for a subsequent assessment paper. Students read a paper then answered questions prior to each session. In the sessions, tutors would lead students through the study and endeavour to generate discussion by, for example, asking students to share their answers. **(B)** Pilot assessment literacy-based literature comprehension intervention. A brief online recorded presentation replaced the first review paper activity and introduces students to the teaching approach and purpose of the assessment. Prior to tutorial 1, students read a primary research paper and answer questions related to the publication. In a revised tutorial 1, students work collaboratively to grade authentic answers with the assessment marking scheme. After grading, group marks are compared with those assigned by faculty. To conclude, tutors and students discuss the question “What makes a good answer?”. Tutors then review answers of different standards, facilitate a discussion on key features that are rewarded and discuss the scientific content of the paper. Tutorial 2 is delivered as in previous years. **(C)** The assessment literacy-based teaching described for tutorial 1 above is implemented in both tutorials.

**Figure 2. Characteristics of an assessment literate individual.**

**Figure 3. Biomedical Sciences: Undergraduate to Practitioner Competency Pyramid.** Using Miller’s pyramid as a framework, the UoE degree finder (2022-2023) and the Subject Benchmark Statement for Biomedical Scientists (2019) were used to identify and map competency development from degree entry to reflective practitioner.

**Figure 4. Biomedical Sciences: Undergraduate to Practitioner Graduate Attribute Pyramid.** Using Miller’s pyramid as a framework, the University of Edinburgh Graduate Attribute Framework, and the Subject Benchmark Statement for Biomedical Scientists (2019) were used to identify and map graduate attribute development from degree entry to graduation.

**Figure 5. Students tend to award lower marks than faculty.** Comparison of student and faculty grades for 5 questions used in formative tutorial 2 of the literature comprehension teaching. Histogram shows frequency of grades returned from 8 tutorials and dotted line represents mean of grades awarded by two independent markers for question. Student (Mean Error) bias was calculated as an average of the difference between each student grade and the recorded faculty grade for each question. Percentage bias as a function of the actual grade for each question was then calculated. The root mean square error (RMSE) was also calculated to reflect the variation of student grades around the faculty grade.

**Figure 6. Years 1 and 2 of BMS degree are perceived by students as valuable for the development of graduate attributes related to Research and Enquiry.** Year 2 Biomedical Sciences students who had completed the literature comprehension assessment tutorials in 2020 were asked to give examples of

graduate attributes already developed as part of their year 1 and 2 studies at the UoE. 115 answers were returned (from 159 questionnaires) as free text. Eighteen were excluded from further analysis as their meaning was unrelated to graduate attributes or considered ambiguous. The remaining statements were then mapped to the UoE Graduate attribute framework according to mindset, skill group and [sub skill group] (indicated in square brackets). Student statements were then grouped according to their mapping classification and group size totals for each classification calculated. Panel A shows frequencies of statements where classification included 'Research and Enquiry'. Panel B shows frequencies of statements classified as 'Personal Effectiveness', 'Personal and Intellectual Autonomy' or 'Communication'. Panel C shows frequency of statements classifiable as related to the mindsets 'Enquiry and Lifelong Learning', 'Aspiration and Personal Development' or 'Outlook and Engagement'.

**Figure 7. The assessment literacy intervention focused students on the development of graduate attributes rather than domain specific knowledge.**

Year 2 Biomedical Sciences students who had completed the Literature comprehension assessment tutorials in 2020 were asked to define the most important thing they had learned from the teaching. 142 responses were returned (from 159 questionnaires) as free text. Thirteen responses were excluded from further analysis as the meaning was unclear or considered ambiguous. The remaining statements were then individually mapped to the UoE graduate attributes according to mindset, skill group and, where possible, [sub skill group] (indicated in square brackets). Student statements were then grouped according to their mapping classification and group size totals for each classification calculated.

**Table 1. Positive impact of assessment literacy intervention on student confidence in literature comprehension assessment.** Year 2 Biomedical Sciences students who had completed the literature comprehension assessment tutorials in 2020 were asked to respond to nine statements related to their understanding of assessment and the outcomes of the assessment literacy tutorial teaching. Table shows 159 responses recorded using a Likert scale as follows: Strongly Disagree (SD), Disagree (D), No Strong Feelings (NSF), Agree (A), Strongly Agree (SA), Not Applicable (N/A).

Question	SD	D	NSF	A	SA	N/A	Total
I have a good understanding of how my assessments have been marked up to this point in my degree	1	14	32	78	33	1	159
I don't think it is necessary to understand how our assessments are marked	126	21	5	4	2	1	159
The Literature Comprehension tutorials helped me understand more about different standards in assessment	0	0	18	65	74	2	159
The Literature Comprehension tutorials helped me understand how to prepare for the literature comprehension exam	1	1	17	69	69	2	159
The Literature Comprehension Tutorials helped me feel more confident in communicating my scientific interpretation and reasoning	1	9	34	77	36	2	159
The Literature Comprehension Tutorials have made me consider what a reader needs to know	0	8	22	69	58	2	159
The Literature Comprehension Tutorials have helped me understand how to evaluate and use data to support my interpretation	1	5	33	76	42	2	159
I enjoyed the literature comprehension tutorials	3	7	36	83	28	2	159
I would like similar tutorials in my other courses	2	16	21	63	55	2	159

**Table 2. The development of graduate attributes is highly valued by undergraduates.** Year 2 Biomedical Sciences students who had completed the literature comprehension assessment tutorials in 2020 were asked to respond to three statements related to graduate attribute development in their degree. Table presents data from 159 responses recorded using a Likert scale as follows: Strongly disagree (SD), Disagree (D), No Strong Feelings (NSF), Agree (A), Strongly Agree (SA), Not Applicable (N/A).

Statement	SD	D	NSF	A	SA	N/A	Total
The development of graduate attributes is an important part of my degree	0	0	12	59	88	0	159
I know when teaching activities are contributing to the development of my graduate attributes	4	9	49	72	25	0	159
I don't think it is important for me to understand how graduate attributes are developed	86	57	8	6	2	0	159

In review

**Table 3. Questions used in focus groups intended to analyse long term impact of assessment literacy intervention.**

<b>Questions regarding Literature Comprehension tutorials</b>
<ol style="list-style-type: none"><li>1. What did you think the main purpose of the literature comprehension tutorials and assessment was?</li><li>2. How did the tutorials and assessment help to improve your ability to analyse and discuss a paper?</li><li>3. How did the tutorials and assessment help you (or not) to understand the assessment process?</li><li>4. Did the tutorials make you feel more confident about the assessment? In what way?</li><li>5. Do you think the tutorials came at the right time in your degree? When would be the best time to bring these in?</li><li>6. Did the tutorials help you understand where the exercise fitted in to your overall degree development and how?</li><li>7. Can you tell us some things you learned from the tutorials that have applied or think you will be able to apply in other settings?</li></ol>
<b>Questions regarding Graduate attributes</b>
<ol style="list-style-type: none"><li>1. What kinds of things you're learning about now do you think you will be able to use in your future careers?</li><li>2. What, in your mind, are the key graduate attributes a Biomedical Sciences student needs to have gained when they complete their degree?</li><li>3. Do you think you've had the opportunity to develop any of these attributes so far in your degree – if yes, please give us some examples.</li><li>4. At the time, did you realise you were developing a graduate attribute?</li></ol>

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In review



**Author contributions:**

KR conceived and conducted the study, collected, and analysed the data and wrote the manuscript. KH performed the study and analysed the data. SR contributed to the development of the study themes, critically guided the study, and reviewed the data. All authors reviewed and edited the final submitted manuscript.

**Limitations:**

At the outset of this project, a key aim was to evaluate the year-on-year effect of the assessment literacy intervention on overall class grades. Ultimately, this was not possible due to changes in delivery of the assessment in response to the SARS-CoV-2 pandemic. In 2020, the exam moved from a 90-minute invigilated format to an online assessment undertaken over a 24h period. For both academic and practical reasons, this online delivery method has been retained and, with no like-for-like comparison possible, we have not sought to directly test whether our intervention had a positive effect on cohort grades.

**Conflicts of Interest and funding:**

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

**Ethical approval:**

Ethical approval for both the survey and focus group were obtained from the Social Research Ethics Group (SREG), Deanery of Biomedical Sciences (sub-group of the Research Ethics Committee, School of Health in Social Science, University of Edinburgh).

**Data availability:**

The datasets presented in this article are not readily available per ethics approval. Further enquiries should be directed to [kevin.robertson@ed.ac.uk](mailto:kevin.robertson@ed.ac.uk).

**Acknowledgments:**

We gratefully acknowledge that funding for this PTAS project was provided by the University of Edinburgh Development Trust. We wish to thank Dr Allison Wroe, Dr Douglas Roy, and Dr Simon Talbot for their continued, invaluable help in teaching and data collection. We are also grateful to Dr Thamarai Dorai-Schneiders for enabling and supporting changes to teaching practice.

## Supplementary Data and Information

**Table S1. Course level learning outcomes for the year 2 course UoE Biomedical Sciences course Microorganisms, Infection, and Immunity 2.**

Course level learning outcome 4 refers to the teaching and assessment integral to the Literature Comprehension Assessment.

<b>By the end of the course, students should be able to:</b>	
<b>1</b>	Describe the structural organisation, metabolism, growth processes and genetics of microorganisms. Explain how pathogen structure and physiology relates to infection and survival within the host. Describe mechanisms by which infection can lead to disease and immune pathology, using selected examples of microorganisms where appropriate.
<b>2</b>	Describe the functions and characteristics of the innate and adaptive arms of the immune system. Explain the roles of the key innate and adaptive immune cells, and how they work together to recognize, respond to, and kill pathogens. Provide an overview of how uncontrolled immune responses can lead to disease and immune-mediated pathology.
<b>3</b>	Describe how immune-related (e.g., vaccination) and non-immune (e.g., drug treatments, hygiene) approaches can be used to control infection. Explain how an immune component (antibodies) can be generated and applied as a tool for experimental research or for the therapeutic treatment of diseases.
<b>4</b>	Extract, summarise, and interpret information contained within selected primary scientific research papers pertaining to the areas of infection and immunity.
<b>5</b>	Perform practical procedures to produce accurate results, explain the theoretical basis of the techniques employed, integrate information from lectures and practicals to interpret experimental data and answer questions related to the implications of their work in a wider context.

**Table S2. Deanery-wide end of course survey questions (2019) used to gather feedback on Literature comprehension tutorials and assessment.**

<b>Likert scale questions</b>
Tutorials were interesting, relevant, and useful.
My tutor was knowledgeable and helpful.
The tutorials helped me to learn how to read scientific literature.
If you have received feedback from your Literature Comprehension Test, the feedback received was useful.
The Literature Comprehension tutorials were well organised.
The learning aims of the Literature Comprehension tutorials were clear.
The Literature Comprehension tutorial 2 session helped me understand more about different standards in assessment.
The Literature Comprehension tutorial 2 session helped me better understand how to prepare for the Literature Comprehension exam.
<b>Free text questions</b>
Any comments on the tutorials - e.g., what did you like/dislike about them, could they be improved?

**Table S3.** Free text responses to the request “Can you give examples of graduate attributes you think you have already developed as part of your studies at the University of Edinburgh? that were excluded from the mapping and analysis.

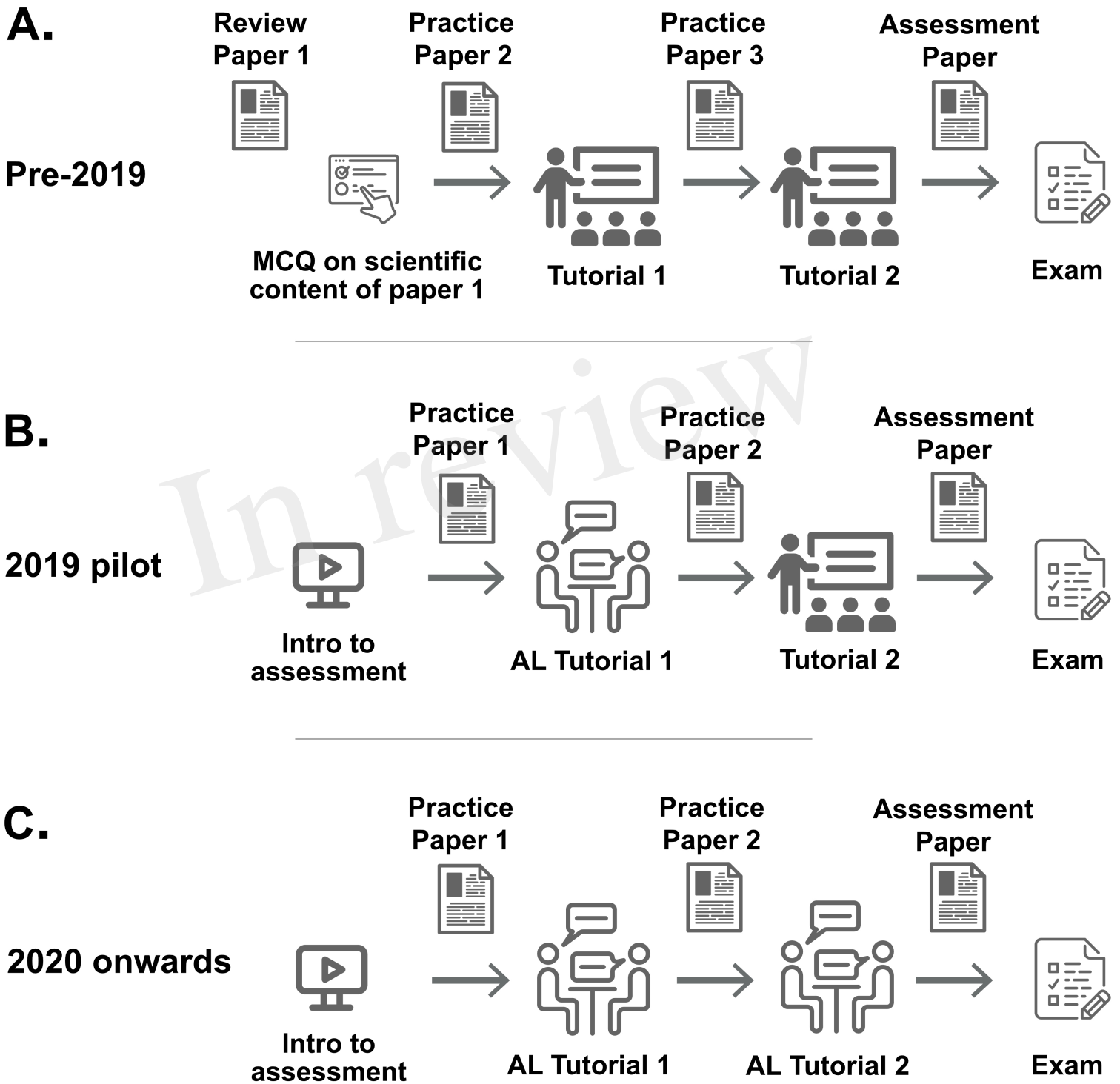
“Tutorial skills”
“Technical scientific skills”
“Skills and knowledge required for non-research related lab work”
“Understand information obtained from journals/lectures and apply it - tutorials/exams/coursework/practical”
“Academic discussion”
“Becoming more comfortable with scientific literature”
“Experimental skills – practical”
“I developed the practical skills”
“Lab experience”
“Lab skills”
“Lab techniques”
“Lab work”
“Many different lab techniques during practical work”
“Practical skills”
“Understanding how to correctly structure answers in the exam to get marks through peer-review and looking at marking scheme”
“Knowledge in my degree area”
“Some courses require extensive reading so efficient method to grab key points from a lot of reading”
“Knowledge related to everyday life”

**Table S4.** Free text responses to the statement “The most important thing I learned in the MII2 Literature comprehension tutorials is...” that were excluded from the analysis

“The kind of answers expected in the exam”
“What is expected in the exam”
“A good marking scheme, helpful as usually there are no past paper answers online”
“How the exam is set up - I feel extremely more prepared for the literature comprehension exam now.”
“Practicing a procedure when reading a paper.”
“How to gain marks in long-style questions without deviating from the question”
“How thoroughly the questions have to be answered”
“The standard of marking at this level of university”
“I know what to expect in the exam”
“When describing data and all relevant details, so add everything in whole figure on table”
“Quality over quantity”
“Quality over quantity in answers”
“Quality over quantity”

In review

# Figure 1



## Assessment Literate Individual



**Knowledge, Attributes & Skills**

### Engage in...

Monitoring own learning

Reflective practice

Development of skills to improve learning and performance

### Understand...

How assessments contribute to learning and progression

How assessments are undertaken

### Use...

criteria for self or peer assessment

### Able...

To use an appropriate relevant method for any given assessment

Figure 3

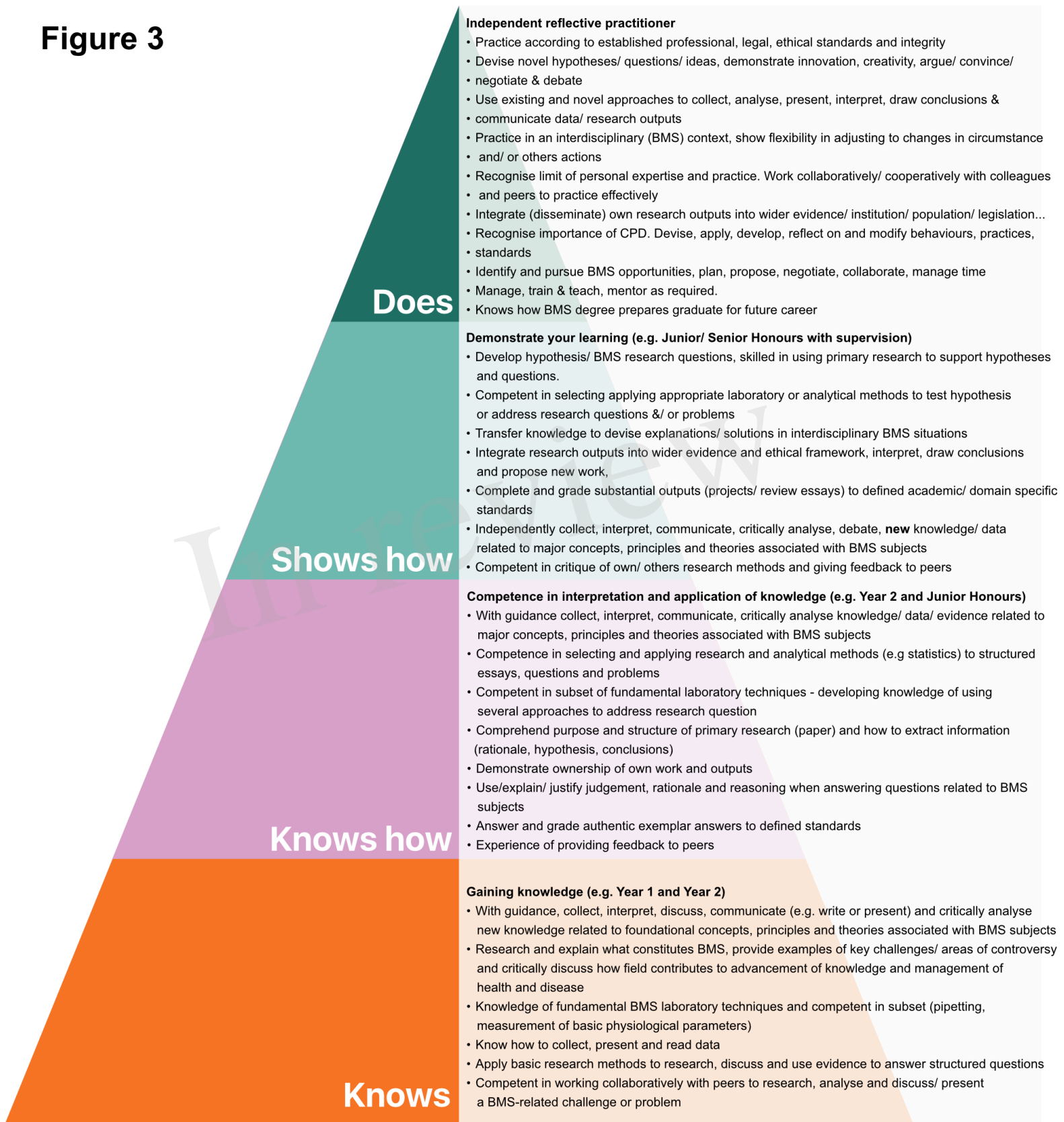
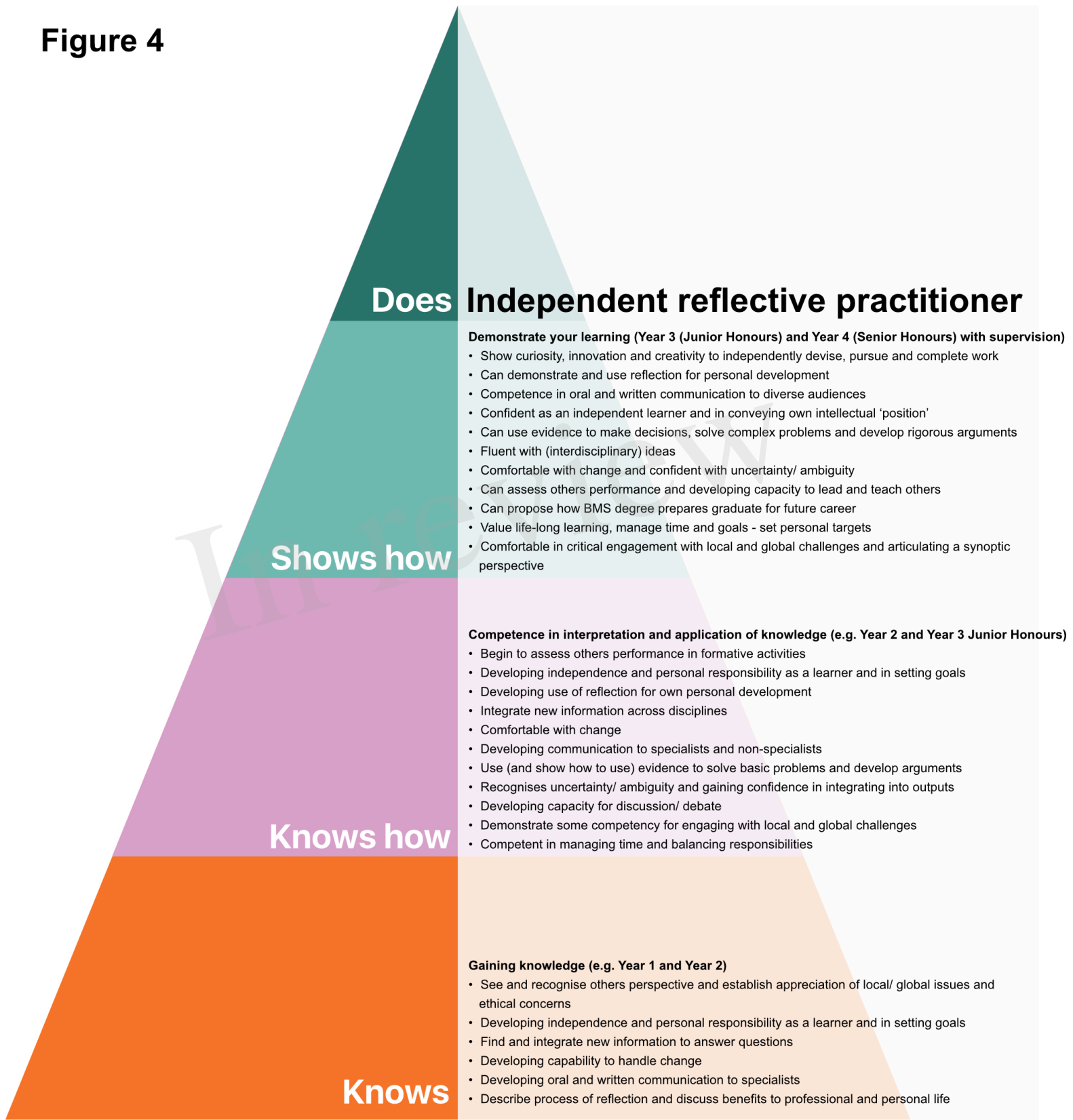


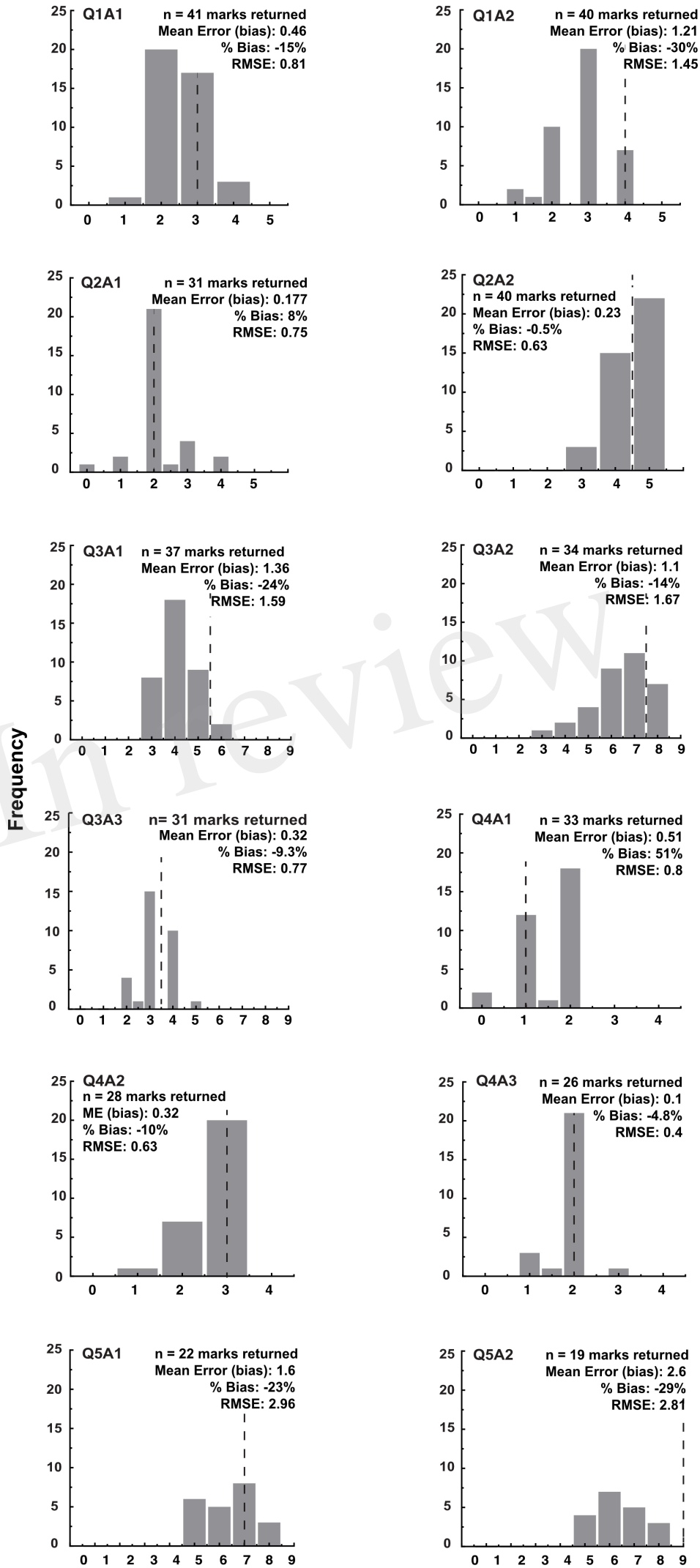


Figure 4



# Figure 5

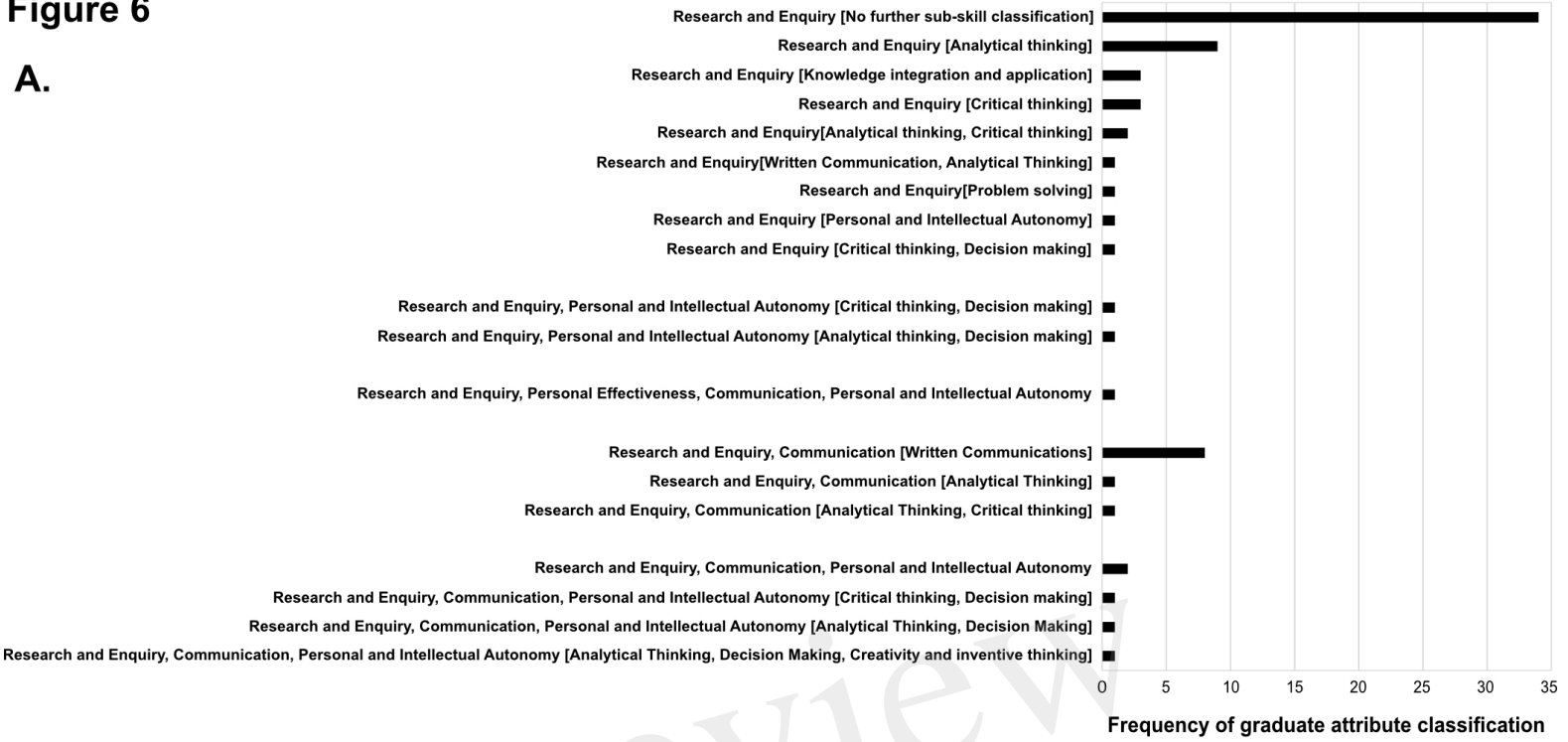
Figure 5.JPEG



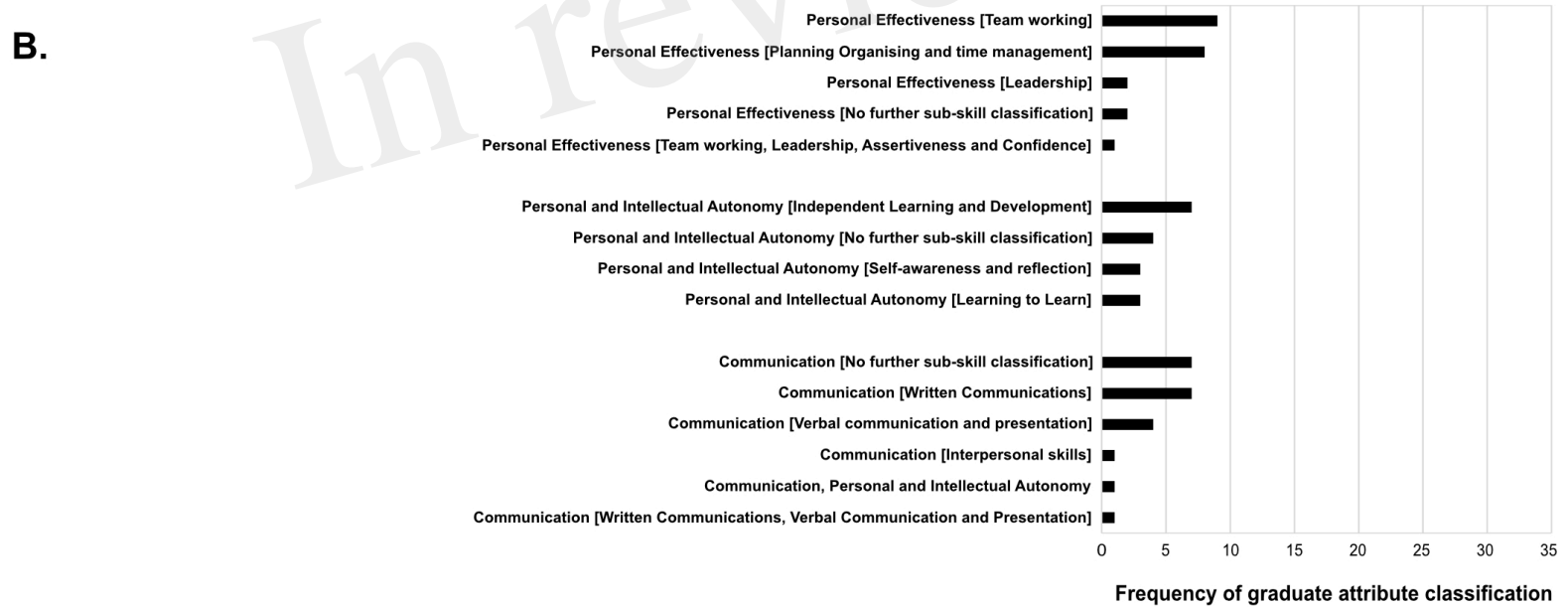
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Figure 6

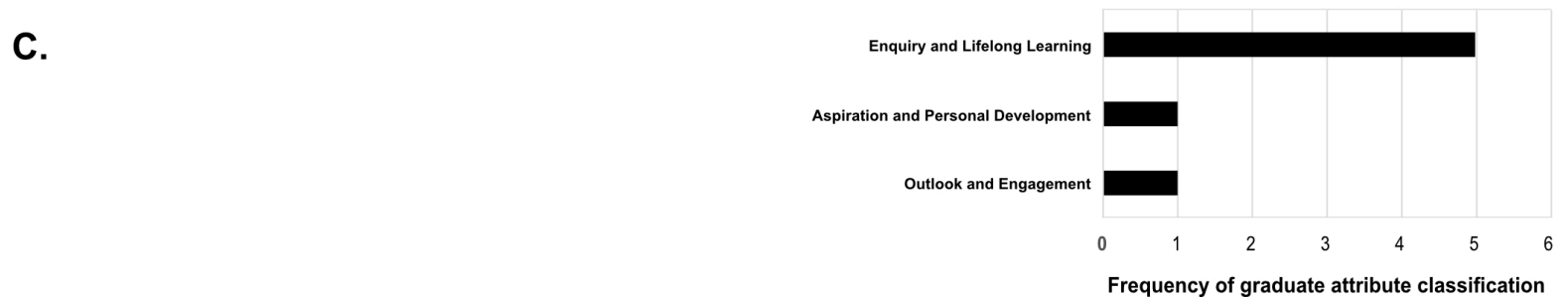
A.



B.



C.



In review

Figure 7

