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A grading matrix assessment approach to align student performance to Threshold Learning Outcomes (TLOs) in a large first year biology class

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Abstract

In our large first year biology course, we aim to provide students with clear links between the course delivery framework and assessment. In the first semester of offering in 2008, we determined grades using the traditional weighted average of marks for the assessment tasks. However, of the 99% of students who passed with an aggregate of at least 50%, the lowest performing student obtained only 21% for the examination. Since Semester 2 2008, we have graded the course using a grading matrix approach with specified standards for all the individual assessment components. Analysis of results from this approach showed that 85-89% of students obtained a passing grade, for which a minimum score of 45% for the examination was required. The grading matrix approach provides a measure of each student's higher order learning of concepts and skills that can be mapped to threshold learning outcomes for the students' programs of study.

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Introduction

Assessment, and the method by which the results for summative graded tasks are aggregated to determine the final grade in a unit of study (referred to subsequently as a course), are known to have a major impact on student engagement with and learning of the course material (Wiggins, 1998). The traditional method for determining course grades is by calculating the weighted average of marks for the summative assessment tasks (Sadler, 2005), and this is still the most common method for grade determination in Australian universities. However, this method is highly problematic as poor performance in one area of assessment in the course is masked by good performance in another (Sadler). Hence, students obtain passing grades for courses, despite their performance in the assessment tasks failing to meet several of the learning objectives. When this process occurs for multiple courses across a student's program of university study, then it is highly likely that students may be graduating from universities without meeting threshold learning outcomes (TLOs) for their programs. In addition, the records for any particular student's performance across the university courses they study usually do not provide easily accessible information regarding the standards they have reached in each of the TLOs for their program. This issue is particularly important in the context of the Tertiary Education Quality and Standards Agency (TEQSA) and its reference to learning standards as "outcome standards [that describe the] ... nature and level of student attainment" (TEQSA, 2011, p3) and the development of TLOs for graduates in most of the major areas of university study (Australian Learning and Teaching Council [ALTC], 2010, 2011). Krause, Barrie, Scott, Sachs, and Probert (2012) have highlighted the need for informed and evidence-based debate around the issues associated with implementation of teaching and learning standards across the tertiary sector. Grading of students will need to provide the depth of information required for universities to be able to assert that students who are graduating from their programs have met the required standards for the relevant TLOs. In addition, it is very important to achieve engagement of students with this change in focus of grading their performance, from the first year of their university studies (Donnison & Penn-Edwards, 2012; Nelson, Clarke, Stoodley, & Creagh, 2014).

This report addresses the issue of how to aggregate grades and marks in assessment tasks to give a course grade that reflects the student's overall performance in a large first year biology class. Specifically, we used an approach that measures both the content knowledge as well as the cognitive depth to which such knowledge was acquired by any particular student, as highlighted in the best practice models for assessment and alignment (Näsström & Henriksson, 2008) such as the Bloom's revised taxonomy (Krathwohl, 2002). The assessment approach described here can also be easily applied to courses from other disciplines as well as those from second or third year level of undergraduate study. Our aims were (i) to provide a measure of student performance in each of the areas relevant to the learning objectives of the course (which map to graduate attributes and TLOs of the students' programs), and (ii) to aggregate student performance to give a grade that reflects the achievement of minimum levels of performance in each of those areas. We are particularly concerned to ensure that students in our first year biology course have sufficient knowledge of cellular and tissue biology at the end of the course (as measured by their examination performance) to underpin their future studies in physiology and related areas. In the past, this has been assumed to have been done well by universities, but the effects of grading with weighted averages show that this may not necessarily have been so. In addition, we want the students to know the standard of their performance in areas relevant to other graduate attributes, such as scientific inquiry, practical competence and communication, at the end of the first year biology course. Students need to be able to take their standards of achievement in each of the areas relevant to the TLOs for their university program forward to their continuing university studies. This will be essential for the university to be able to warrant that a student eventually meets the minimum standards required to graduate, as well as higher standards of achievement, in the areas addressed by the TLOs (Oliver, 2011).

Students can only obtain a passing grade in our course if they achieve minimum standards in all of the grading areas deemed to be of importance. One proposal for grading to achieve these aims involves the determination of a number of grading areas (e.g. 3) relevant to the course and ensuring that all assessment tasks in the course have elements relevant to these areas (Green & Emerson, 2007). The student work can then be assessed as achieving the level of "impressive" or "expected" or "not reaching the expected-level" for each of the grading areas (Green & Emerson, 2007, p501). In contrast, the grading matrix that we have implemented in our course defines the grading areas based on the course learning objectives (which are related to the TLOs for the students' programs). We devised appropriate summative assessment tasks that predominantly give information about the standard of performance in only one of those grading areas. Then, we aggregated student's performance in each of the tasks for a particular grading area to give a grade or mark for that grading area, judged against the minimum required in that area for each overall grade (7 to 1) for the course. A student's final grade for the course is then determined by the area in which they perform at the lowest level compared with the minimum standards required for each grade. The matrix assessment is hence an example of the use of a disjunctive grading rule (Sadler, 2005, 2009).

Methods

Course and institutional context

Cells to Organisms (BIOL1040) is a course that was completed by 474 to 803 students in each of the four semesters relevant to this study in 2008 and 2009, at a large, research-intensive Australian university delivering a comprehensive tertiary education program. The course is still offered and now has an enrolment of approximately 850 students in each of two semesters each year. The students who study BIOL1040 are enrolled in a range of different programs, with many of the students in Science programs (e.g. Bachelor of Science, Biomedical Science or Biotechnology) or professional degree programs (e.g. Bachelor of Pharmacy, Bachelor of Dental Science, or Bachelor of Health, Sport & Physical Education), with smaller numbers of students enrolled in a range of other programs, including the Bachelor of Engineering or Bachelor of Arts. For the majority of students, BIOL1040 is a foundation course that is required for later studies in such areas as physiology, anatomy, pharmacology, zoology, botany and a range of related clinical areas, and is taken by most students in their first or second semester of university study.

(b)

BIOL1040 LEARNING OBJECTIVES

1. Explain and discuss specific examples of biological research in different communication modes and forums
2. Demonstrate core competency in basic biological laboratory techniques
3. Demonstrate sound scientific reasoning in the context of practical sessions
4. Appreciate the processes that scientists use to discover and verify new knowledge
5. Demonstrate Quantitative Skills (QS) and their application in biology
6. Work effectively in teams to achieve sound academic outcomes
7. Understand the control, integration and coordination mechanisms that are required to maintain a functional organism
8. Appreciate that organismal diversity is reflected through the biological adaptation among species
9. Describe the structure and function of major organ systems
10. Demonstrate an understanding of how pathways of intercellular and extracellular communication are integral to homeostasis
11. Demonstrate how support and movement are related
12. Describe the physical and electrochemical properties of cell membranes in terms of excitable and non-excitable cells
13. Relate the internal transport and delivery of gases, nutrients and messengers to the organ systems of relevant systems
14. Explain homeostatic mechanisms in plants and their differences compared with corresponding systems in animals
15. Appreciate the interdisciplinary nature of biological systems

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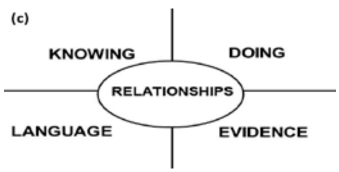

Figure 1: **The course BIOL1040 *Cells to Organisms* is based on (a) six key organising principles, leading to (b) the course learning objectives, and (c) is delivered using the operational model shown**

Organisation and assessment for the course BIOL1040 Cells to Organisms

The course BIOL1040 is based on six key organising principles or aims (Figure 1a), from which the course learning objectives are derived (Figure 1b). The learning activities comprise three 50 minute lectures per week, five 3 hour practicals and a 50 minute peer-assisted study session per week in the 13 week semester. Commencing in the first lecture of the course, we discuss the learning activities and related assessment tasks with the students in relation to an operational model linking “knowing” and “doing” science with the nature of “evidence”, the “language” used and the “relationships” that develop between students, lecturers and tutors (Figure 1c). It is important to note that the images provided in Figure 1 are taken directly from our course resources, which the students have access to throughout the semester. We discuss these aspects with the students in the first introductory lecture as well provide them with a copy of the information via the course Blackboard site and electronic course profile.

In the first semester that the course was offered (Semester 1 2008), the assessment consisted of: 5% for mastery of 5 practical core competencies, 15% for scaffolded reports on each of 5 inquiry-based practicals, 40% for Communication activities based on a Personal Response (Moni, Moni, Lluka, & Poronnik, 2007) and an econference (Moni, Moni, Poronnik, & Lluka, 2007), and 40% for an end of semester examination. The examination was 73% multiple choice questions and 27% short answer questions, and was based on both the lecture and practical course material. The grades for the students were determined as the weighted average of their marks for each of these assessment components, and hence allowed unrestricted trade-offs (Sadler, 2009).

In the subsequent semesters, and in particular Semester 2 2008 and Semesters 1 and 2 2009 reported here, a grading matrix was introduced (Figure 2) and grades were determined using a conjunctive grading rule (Sadler, 2009), where students were required to reach a minimum threshold in each of the four areas of Practical Reports, Practical Core Competencies, Communication and

BIOL1040 Grading Matrix - Minimum standard for each grade shown							
	7	6	5	4	3	2	1
Practical Assessment [average of best 4 from 5 reports; 1st is formative]	A	B	B	C	C	D	E
Practical Core Competencies [4]	Competent	Competent	Competent	Competent	Not Competent	Not Competent	Not Competent
Communication [Personal Response & eConference (average of 5 results)]	A	B	B	C	C	D	E
Knowledge [End of Semester Examination]	80%	70%	60%	45%	42%	35%	0

Figure 2: **The grading matrix used to determine the course grade for BIOL1040 from Semester 2 2008. The average of the marks/grades for each horizontal section was compared with the required minimum for each course grade, with no averaging in the vertical direction**

Knowledge in order to be awarded grades from 7 (best) to 1 (worst), with grades of 4-7 being passing grades. This implements the university grading scale, which is not based on percentages, but on descriptors such as those illustrated in Figure 3 for the grades of 4 and 7. The Communication and Practical Report tasks were graded from A (best) to E (worst) using criteria and standards rubrics, and Practical Core Competencies were graded "Competent" or "Not Competent" as mastery tests with multiple attempts allowed. Examinations were marked in the traditional way with marks awarded based on the student responses and were not different in difficulty or format from those in Semester 1 2008.

Analysis of student grades and examination performance

In this study, the grades obtained by the students and in particular their examination results (as a measure of their knowledge of the course material) were analysed for four semesters, including Semester 1 2008 (grades determined using the weighted average of marks) and the subsequent three semesters when the grading matrix was introduced and used to determine the students' grades for the course.

Results

In the first semester of offering BIOL1040 (Semester 1 2008), using the traditional weighted average approach to determine the course grades, 99% of the 474 students passed the course (grades of 4-7). However, given that the end of semester examination is our measure of the students' knowledge of the course material that they will be taking forward into their subsequent studies, we were very concerned to find that this resulted in students with marks in the examination as low as 21% but obtaining a passing grade. For this reason, we changed to the use of the grading matrix (Figure 2) from Semester 2 2008. Figure 4 shows that implementation of the grading matrix resulted in 85-89% of the students obtaining a passing grade in BIOL1040 in the subsequent three semesters.

After introduction of the grading matrix for assignment of grades, the students could no

4 - Pass. Demonstrates adequate understanding and application of the fundamental concepts of the field of study; develops routine arguments or decisions and provides acceptable justification; communicates information and ideas adequately in terms of the conventions of the discipline.

....

7 - High Distinction. As for 6, with consistent evidence of substantial originality and insight in identifying, generating and communicating competing arguments, perspectives or problem solving approaches; critically evaluates problems, their solutions and implications.

***Figure 3*: The university-wide descriptors for course grades, showing descriptors for grades of 4 (Pass) and 7 (High Distinction) as examples. Course coordinators are required to aggregate the assessment marks/grades in the course such that the students awarded each grade meet the requirements of the corresponding descriptor**

longer obtain a passing grade in the course unless they obtained at least 45% in the end of semester examination. Hence, the knowledge that the students who passed the course could potentially take forward to subsequent study in related areas was much greater than in Semester 1 2008, when students passed the course with as low as 21% in the examination. In Semester 1 2008, 74 students (15.6% of the total cohort) obtained a passing grade but achieved less than 45% in the final examination, with 58 of these students being awarded a grade of 4 and 16 awarded a grade of 5. The grade creep associated with grading with the weighted average of marks (actual student grades in Semester 1 2008) and even the use of a hurdle for the examination (for analysis purposes only) is evident in Figure 5.

The application of a hurdle of 45% for the final examination overcomes the problem of students passing despite apparently poor levels of knowledge of the course material. However, there is still the same grade creep for grades of 5-7 as there is when a weighted average of marks is used for assignment of grades. This occurs because achieving grades of 5-7 still only requires a hurdle of 45% for the final examination in that grading system, so there are very few students who are awarded a grade of 4 when only a hurdle on the final examination is applied. On the other hand, when the entire grading matrix was retrospectively applied (only for the purposes of analysis) to the students' results for Semester 1 2008, with student performance on the final examination (and other areas of assessment) required to be progressively more superior for each higher grade (Figure 2), a feasible distribution of grades was obtained (Figure 5).

The results in Figure 6 further focus on the achievements of the students in the Knowledge component of the grading matrix for the course (i.e. their % for the final examination). The percentage of the students who passed the course and achieved a sound knowledge of the course content (as measured by 60% of greater in the final examination) increased from 52% in Semester 1 2008 prior to introduction of the grading matrix to 71-72% in the three semesters following introduction of the grading matrix (Figure 6). The percentage of passing students who achieved 80-100% in the final examination increased from 9.4% in Semester 1 2008 to 21-26% in the subsequent three semester with the grading matrix (Figure 6). There was an overall increase of 3-5% in the average examination scores obtained by all of the students in Semester 2 2008 (64.7%), Semester 1 2009 (65.4%) and Semester 2 2009 (63.3%) compared with Semester 1 2008 (60.5%), despite a very deliberate and considered attempt to maintain the same examination format and difficulty as closely as possible.

Despite the use of the grading matrix and the consequently more challenging assessment environment for the students, BIOL1040 has always ranked more highly in student evaluations than the other large first year Science courses at the university and the ranking did not reduce when the grading matrix was introduced. The evaluation rankings were 3.83 in Semester 1 2008 and 3.91-4.05 in the subsequent three semesters, compared with an average of 3.6 for the other first year Science classes on a 1 (low) to 5 (high) scale.

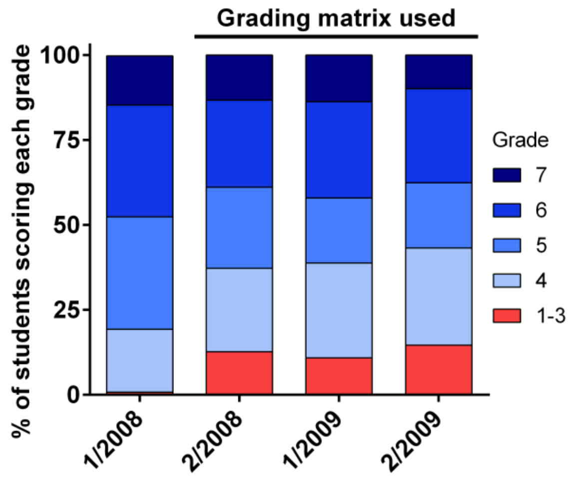

Figure 4: **The % of students who obtained each of the passing grades (7, 6, 5, and 4) or a failing grade (1-3) in Semester 1 2008 (prior to introduction of the grading matrix when grades were based on the aggregate mark) and in the subsequent three semesters when a grading matrix was introduced. The number of students in the course in the four semesters were 474 in 1/2008, 738 in 2/2008, 593 in 1/2009, and 803 in 2/2009**

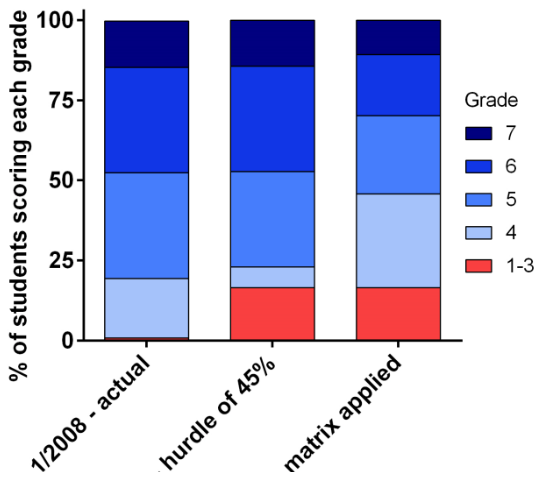

Figure 5: **Retrospective and hypothetical analysis of the results obtained by the 474 students in Semester 1 2008 to show the effects that applying a hurdle of 45% for the final examination and applying the grading matrix would have had on their grades**

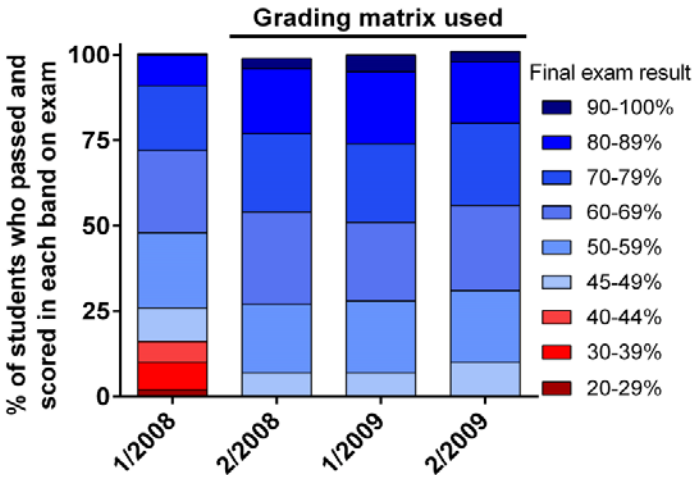

***Figure 6*: Student achievement in the final examination for the passing students in Semester 1 2008 (grades determined as an aggregate mark) and the subsequent three semesters after introduction of a grading matrix. The number of passing students in the course in the four semesters were 470 in 1/2008, 644 in 2/2008, 528 in 1/2009, and 686 in 2/2009**

Discussion

We had been concerned for some time that the use of aggregated marks for grading students in our foundational biology course resulted in some students with very low levels of achievement in the final examinations still passing the course and continuing on to subsequent advanced courses within the discipline. The use of aggregated marks provides a disincentive for students to prepare at the highest level for the final examinations if they are already close to the overall marks required to pass or achieve a particular passing grade in the course. A major problem with this approach is that poor performance in one area of the course is masked by good performance in another area, so students can be granted a passing grade, without meeting all of the learning objectives of the course (Sadler, 2005). This then has flow-on effects throughout the student's undergraduate program of study, because students can proceed to the subsequent courses in their programs without being adequately prepared by appropriate levels of achievement in their earlier courses.

One solution to this issue that has been introduced recently, for example, in most Science courses in our university is to apply a minimum hurdle for performance in the final examination in order to achieve a passing grade for the course. However, the retrospective and hypothetical analysis of our data for BIOL1040 in Semester 1 2008, shows that this approach results in grade inflation, because the hurdle is a requirement for the first passing grade (Pass), but there is not a requirement for superior levels of performance for the higher grades (Credit, Distinction and High Distinction). Hence, with examination hurdles, there are very few students who are graded as a Pass, which clearly does not reflect the real level of achievement for the students, as they are granted superior grades without actually achieving superior levels of performance in each of the areas required by the course learning objectives. Our data for retrospective analysis of the results for the Semester 1 2008 BIOL1040 class also showed that the implementation of a grading matrix, where minimum levels of achievement are required for each grade, would overcome this problem of grade creep and result in an appropriate grading of the students based on their level of achievement in each of the key areas of the course.

Based on this analysis, we introduced the grading matrix for the assessment of BIOL1040 in Semester 2 2008 and analysed the effects on student grading for the next three semesters. However, as highlighted by Green and Emerson (2007), the implementation of a grading matrix requires very careful selection of the areas on which grading is to be based, because all of the areas assume equal importance in determining the students' grades in the matrix approach. This contrasts with the application of different weightings for specific assessment tasks in aggregating scores to determine grades. Our experience was that the introduction of the grading matrix required the course teaching team to have a very robust and beneficial discussion about the aspects of the course learning activities and assessment that were valued highly, and hence how they should feature in a grading matrix. It is also very important to note that the grading matrix specifies the *minimum* level of achievement required in *each* area of the matrix in order to be granted the relevant grade. Since there is no averaging across the areas to determine student grades, it is important that the minimum level of achievement is set at a carefully planned and realistic level.

The introduction of the grading matrix resulted in a clear increase in the level of achievement of the students in the knowledge component of the course, as measured by their performance in the final examination. This should have prepared the students more rigorously to take this knowledge forward into subsequent courses based on this material. We are currently investigating the vertical integration of this first year course with second and third year physiology courses in another project. The grading matrix makes this clearly evident in the students' results and avoids the loss of the patterns of strengths and weaknesses of the student's performance that occurs in the aggregate method of determining grades (Sadler, 2005). Also, the distribution of grades in BIOL1040 after introduction of the grading matrix (Figure 4) shows that we have avoided the inevitable grade creep that occurs with the alternative approach of the use of hurdle levels of achievement in the final examination.

One aspect of the use of the disjunctive grading matrix that is very important is the possibility for students to fail an assessment task in a particular area, and still be able to improve their performance in that area throughout the semester and pass the course. This can be achieved by ensuring that there is more than one assessment task in each area of the grading matrix (as occurs in the BIOL1040 matrix for practical reports and communication) or multiple opportunities to attempt mastery tasks (as occurs for the BIOL1040 practical competencies). However, in the grading matrix as applied in the first three semesters for which the data is presented here, there was only one opportunity to meet the requirements of the Knowledge component of the matrix assessment and that was the final examination. This issue has been overcome more recently by the introduction of three quizzes each worth 5% towards the Knowledge mark, with the remaining 85% being obtained in the final examination.

There are, however, some drawbacks in the introduction of a grading matrix in courses, particularly while it is a relatively uncommon approach to grading within the university. Students find the matrix approach more difficult to understand, so we have spent significant time and effort in progressively explaining how their grades will be determined with the matrix progressively throughout the semester. Sadler (2005) has highlighted this as a requirement of the use of mechanisms other than aggregation of marks to determine student grades. Nevertheless, it appears that this has been relatively successful for BIOL1040, in that the evaluation scores for the course have not been adversely affected since the introduction of the grading matrix. Students clearly prefer the final examination to be low stakes, although this has become less common at our university now that most Science courses have a final examination performance hurdle to obtain a passing grade.

This study addresses issues that are relevant to the teaching and learning standards domain within TEQSA and in particular the importance of being able to assure graduate outcomes at the required minimum standards of the TLOs for the students' program of study, as set out in several recent discussion papers (ALTC, 2010, 2011; Krause et al., 2012; Oliver, 2011; TEQSA, 2011). The current common method of aggregating marks to determine student grades with its compensatory approach to poor performance in one area by good performance in another area of the course (Sadler, 2005) is not compatible with the requirement for universities to be able to warrant that their graduates have achieved the minimum standards required for the TLOs. The grading matrix approach, on the other hand, does record student achievement in each of the areas in the matrix, and these can be aligned to the areas in the TLOs. Hence, we assert that the widespread introduction of a grading matrix approach for grading of student performance in university courses would allow a record to be kept of the standard of achievement by each student in each of the areas of the TLOs across their university program. Universities would then be able to warrant that their students meet the appropriate minimum standards in each of the TLOs at each level of their program and hence overall at graduation. In addition, the grading matrix also provides information about superior performance in the TLOs by students who obtain higher grades than the minimum pass.

Conclusion

A grading matrix that requires students to reach minimum standards in the four areas of practical reports, practical competencies, communication and knowledge was discussed for assessment in a large first year biology course. The main aim was to overcome the problem of students passing the course with low levels of achievement in the knowledge component of the assessment. The introduction of our grading matrix has resulted in an increase in student engagement with all aspects of the course and its associated assessment, and, for the passing students, a measured and appropriate level of achievement in each area to carry on to the subsequent related courses in their programs. This approach provides a mechanism for universities to meet the TEQSA requirements to warrant that all students graduating from Australian universities meet the TLOs for their program of study.

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