Studies in Higher Education

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/cshe20

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To cite this article: Angelito Calma & Martin Davies (26 Feb 2025): Assessing students' critical thinking abilities via a systematic evaluation of essays, Studies in Higher Education, DOI: 10.1080/03075079.2025.2470969

To link to this article: https://doi.org/10.1080/03075079.2025.2470969

Published online: 26 Feb 2025.

STUDIES IN HIGHER EDUCATION
https://doi.org/10.1080/03075079.2025.2470969

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Taylor & Francis Group

Assessing students' critical thinking abilities via a systematic evaluation of essays

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ABSTRACT

In this paper, we address critical thinking skill assessment in the context of management education. This paper uses Ennis' well-known list of critical thinking abilities to identify assessable critical thinking components present in student work. A sample of 152 graduate written assignments designed to assess critical thinking is used as a basis for analysis. These were taken from a business analysis subject in a large Australian business school over a 6-year period. A methodological framework is proposed and applied to this data set, offering a way of assessing evidence of five representative categories pertaining to critical thinking in a business context. The framework includes a basic clarification (BC), bases for inferences (BI), inferences (IN), advanced clarification (AC) and auxiliary abilities (AA). Results indicate that the essays rank highly on AA and AC but low on BC, BI and IN. While critical thinking is partially evidenced in the study corpus, attention is needed in terms of refining the measurement framework dedicated to eliciting specific critical thinking components. We provide the initial elements of such a framework in this paper and make suggestions for how it can be improved. Implications for the theory and practice of management education are outlined.

ARTICLE HISTORY
Received 2 December 2024
Accepted 18 February 2025

KEYWORDS
Critical thinking; management; business; critical thinking operationalisation framework; assessment

Introduction

Critical thinking has long been recognised as a key educational goal (Dewey 1910; Hitchcock 2018). In a recent report, the Organisation for Economic Co-operation and Development (Vincent-Lancrin et al. 2019) recognised 'critical thinking' as an important skill for students to develop. In the twenty-first century, it is especially important to help navigate a complex global environment replete with 'wicked' intractable problems such as climate change and resource shortages. However, it is also well known that tertiary institutions struggle to effectively teach critical thinking adequately (Arum and Roksa 2011; Van Damme and Zahner 2022). Partly this is due to definitional confusion, i.e. about what 'critical thinking' is, partly it is due to a paucity of methods to explicitly teach critical thinking. Critical thinking is an area that is widely lauded as being important, but it is not well understood. The concept is, as Raymond Williams has noted, 'a most difficult one' (1976, p. 76). It remains so.

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Critical thinking has particular and unique relevance in workplace settings. The World Economic Forum *Future of Jobs* report (2023) notes that 'analytical thinking' – a widely-used synonym of 'critical thinking' – is a 'skill on the rise' in terms of its centrality for future employment prospects for graduates. For the projected report period 2023-7, analytical thinking is noted as the second highest – after 'creative thinking' – in a list of desirable skills in a survey of employers, company executives and business leaders encompassing 11.3 million workers across 27 industry clusters and 45 economies around the world. This report placed it well ahead of skills such as 'technological literacy', 'AI and big data', 'talent management', 'quality control' and 'leadership'. Surprising of all – given its increasing importance in this era of great power competition and IP theft – it was also considered more important for employers than 'IT networks and cybersecurity'. In the same report, analytical thinking was top-listed as a skill needed for reskilling employees, trumping skills already listed as well as 'multi-lingualism', 'marketing and media' and a host of other business-critical attributes. The WEF is clear in the desirability of critical thinking for the business sector, but the issue arises as to how well management education prepares students to *be* 'critical thinkers'.

Critical thinking in the business context

How exactly is critical thinking demonstrated in business contexts and how does university prepare students for it? A typical example of critical thinking in a workplace setting is when graduates become part of project teams as contributing team members and decision makers, responsible for projects that need to be completed. In the management context, critical thinking means effectively navigating the complex and chaotic structures of the business or workplace to achieve a desired goal (Coleman, Mason, and Steagall 2012). Management scholars suggest that 'a critical thinker does more than passively accept the ideas of others, including the ideas of business experts' (Dyer 2006, 5) so an attitude of critical discernment is needed. This means weighing up reasons and evidence to inform decision-making. Managers are surrounded by so-called experts, but they are also bombarded by information from a variety of sources and devices to access that information (Chyung, Stepich, and Cox 2006; Conley and Gil 2011). The ideal critical thinker in a management context is the person who can identify what is important and relevant, disregard what could be irrelevant and use reasoned considerations to engage in useful and purposeful actions. Priem (2018) contends that it is the job of a management educator to instil 'a lifelong process of improving critical thinking that can lead to sound judgments (i.e. wisdom) concerning strategic issues' (1). Critical thinking is therefore central to management education, and any employment that ensues for graduates undertaking management education. Business needs critical thinking (Davies and Calma 2020; Hoffman 2023).

Business schools simulate the experience of corporate decision making by putting students into team-based assessments, expecting them to regulate themselves to keep to the task at hand, communicate effectively as a team and perform as a group and individually at an acceptable standard (Ainsworth 2016; De Corte 2016). Management lecturers assume that individuals and groups will display critical thinking abilities through activities such as these and they attempt to foster those opportunities through teaching, learning and assessment activities. The hope is that students use these class-based simulations to develop or enhance their critical cognitive abilities and translate this experience to tackle complex and unfamiliar business activities and contexts when employed in the future (Calma and Cotronei-Baird 2021). However, this is very much an untested assumption, and there is little in the way of models or frameworks to guide such assessment considerations. In this paper we attempt to provide such a framework. We submit that this framework might provide a basis for assessing critical thinking skills in a management context in a more rigorous way; in turn, enabling a systematic way of grading student work.

The present way lecturers assess critical thinking is rather impressionistic and without any 'method' or guiding framework. The assessment methods and rubrics used might typically involve using 'checkboxes' and merely permit the instructor to 'form an impression' about whether the

student has demonstrated 'critical thinking'. They fail to account for fundamental conceptions of critical thinking (Rear 2018) nor contextual and disciplinary differences in critical thinking (Ahern et al. 2012). Nor do they specify precisely what is being assessed when one measures 'critical thinking'. More rigor is clearly needed.

This study examines a sample of written assessments drawn from a masters-level business analysis subject conducted over a six-year period. The assignments were designed to assess critical thinking skills in the context of management education. The paper first aims to determine whether there is evidence of such skills being developed in a management context, beyond the subjective impressions of an assessor, i.e. how true it is that 'critical thinking' is present in written assignments. Second, a formal framework is proposed to engender a new, more precise, way of assessing critical thinking. Current ways of assessing critical thinking lack formality and rely on assessors forming a vague and subjective judgement based on little evidence (Allen, Rubenfeld, and Scheffer 2003; BoarerPitchford 2014; see also Gent, Johnston, and Prosser 1999). We attempt to make progress towards more rigor in this direction. This paper addresses the following question: *Can critical thinking abilities be more accurately measured in written assignments?*

What does it mean to think critically?

What it means to 'think critically' has been a matter of scholarly conjecture since at least the 1930s. Dewey formally described it as an educational goal referring to it as 'reflective thinking' and defining it as: 'the active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusion to which it tends' (Dewey, 1910, p. 6; 1933, p. 9). Doyle (2022, para. 1) suggests that it means 'to analyse information objectively and make a reasoned judgment'. It also means 'self-guided, self-disciplined thinking which attempts to reason at the highest level of quality in a fair-minded way' (Elder and Paul 2007; cited in The Foundation for Critical Thinking 2019, 1). Formal definitions proposed by experts in the field of critical thinking scholarship are many and varied and include:

> … the propensity and skill to engage in an activity to reflective skepticism (McPeck 1981, 8)
>
> … the intelligent use of all available evidence for the solution of some problem (McPeck 1981, 12);
>
> … reasonable, reflective thinking focused on deciding what to believe or do (Ennis 2015, 32)
>
> … the ability to analyse facts, generate and organise ideas, defend opinions, make comparisons, draw inferences, evaluate arguments and solve problems (Chance 1986, 6).

Ennis' definition is certainly the most well known in the literature. Whatever critical thinking is, it has to be *reasonable* thinking (unreasonable critical thinking is a contradiction in terms); it has to be *reflective*, i.e. involve cogitation (as opposed to occurring accidentally or by divine revelation, etc.); and it has to provide a basis for *decision-making* leading to *action*, i.e. it would be absurd to think critically, and then ignore the outcome of one's deliberations. All four facets – reasonableness, reflection, decision-making and resulting action – have to be present, according to Ennis, for thinking to be considered 'critical'.

Calma and Davies (2021) cite a number of other definitions in their analysis of critical thinking in business education (see also Davies 2015). In this study, we follow Ennis and propose a definition of critical thinking suitable for the context of management education and develop a critical thinking framework to identify and analyse evidence of students' critical thinking abilities in a corpus of sample text. This goes some way to address the industry-academia gap between practice and education, a gap considered to be a 'crisis' in business education (Bunch 2020). This gap concerns curriculum not reflecting industry standards, assessment-student performance mismatches, and academics' lack of industry exposure. The stated skill deficits among university graduates, also

includes lack of 'critical thinking' (Robinson 2024). This has led to the dissatisfaction of employers with graduates' ability to cope with the demands of twenty-first-century business challenges (Oliver and de St Jorre 2020). A better understanding of 'critical thinking' in management education, we submit, is central to meeting these challenges.

Defining critical thinking in the context of management education

Below we canvas a widely accepted definition of critical thinking provided by the Delphi Report (Facione 1990, 3). This report drew upon the expertise of 46 professionals from various disciplines. It arrived at a consensus-based view of what 'critical thinking' is. Their definition is as follows (NB: it has been shortened below):

> We understand critical thinking to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation and inference as well as explanation of the evidential conceptual, methodological, criteriological or contextual considerations upon which that judgment was based. Critical thinking is essential as a tool of inquiry. … Critical thinking is a pervasive and self-rectifying, human phenomenon. The ideal critical thinker is habitually inquisitive, well-informed, honest in facing personal biases, prudent in making judgments, willing to consider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in selection of criteria, focused on inquiry and persistent in seeking results which are as precise as the subject and circumstances of inquiry permit. …

They identify a list of six critical thinking *skills* (interpretation, analysis, evaluation, inference, explanation and self-regulation), and a host of critical thinking *dispositions*: inquisitiveness, being well-informed, being honest, prudent, clear, orderly, diligent, reasonable and focussed (the Delphi Report itemises 19 dispositions in total) (Facione 1990). Skills are capacities; dispositions represent the willingness of skills or capacities to be voluntarily exercised. The difference between skills and dispositions is subtle but can be explained with an analogy. A musician can be skilled in such things as technique, musicianship, intonation, phrasing and so on, but it is possible for a highly skilled musician being *in*disposed to exercise their skills (i.e. unwilling to perform, practise, etc.). A good musician needs to have skills *and* the dispositions to exercise them (dedication, commitment and so on). Similarly, a critical thinker needs skills as well as dispositions to use the skills.

We mentioned Ennis (2011, 1; 2015, 32) concise definition of critical thinking as *reasonable, reflective thinking focused on deciding what to believe or do*. He also lists a number of critical thinking dispositions and abilities (see also Ennis 1987). In the context of management, to possess the abilities of a critical thinker, a manager or decision-maker should come up with well-informed decisions based on reasoned consideration of the information available. Borrowing from Ennis and applied to the management education literature, critical thinking might be said to be: *reasonable, reflective thinking focused on making a well-informed decision to meet a managerial goal*. This definition is largely identical to Ennis' definition, and consonant with the Delphi definition, but has more emphasis on management-style decision-making.

Applying a Critical Thinking Framework

In his paper 'Critical Thinking: A Streamlined Conception' Ennis (2015, 32–3) provides a list of 18 critical thinking abilities or skills. These involve basic clarification (1–4), bases for inference (5–7), inference (8–10), advanced clarification (11–5) and auxiliary abilities (16–8) (Table 1). The framework in the present paper uses and attempts to locate the 18 abilities below using student assignment output as a data source. We assign codes to instances of these abilities for ease of reference. We also provide an example of what this looks like in a student essay. In this case, we use a paper on a transhipment optimisation problem for a large shipping company faced with determining the most cost-efficient route from ports of origin to destination ports. We find that 11 out of 18 of Ennis' critical thinking abilities are applicable to the study corpus and analysed our data accordingly.

Table 1. Critical thinking framework as used in the study.

Critical thinking abilities (Ennis 2015)	Code	Expressed as … (core identifiers)	Paragraphs that … (e.g. using a transhipment optimisation problem)
Basic clarification	**BC**		
(1) Have a focus and pursue it	BC1	Identifying the core and sub-questions; formulating a question, particularly in the case of business analysis essays requiring quantitative reasoning; focusing on the (optimisation) question throughout the essay	• Identify the transhipment optimisation problem and consistently refer to it across the essay • Select the most suitable type of ship to utilise • Minimise fuel costs that would also have the effect of reducing environmental damage
(2) Analyse arguments	BC2	Analysing a set of statements (premises and conclusion) that provide evidence, reasons, and grounds for the model, solution or conclusion drawn	• Examine previous investigations into the advantages and disadvantages of using linear programming in maritime transportation
(3) Ask and answer clarification questions	BC3	Not present, required or assessed in the assignment	Not applicable
(4) Understand and use graphs and maths	BC4	Using equations, tables and charts	• Show equations, tables or charts, such as network diagrams of origin and destination ports
Bases for inference	**BI**		
(5) Judge the credibility of a source	BI1	Identifying the types of documents or publications sourced or used in the review of linear programming models; judging the credibility of the sources used in the written essay	• Summarise the previous linear programming models used in similar transhipment problems • Critique the sources such as outlets or databases, if any (but not required in the task) • List the references used
(6) Observe, and judge observation reports	BI2	Observing and judging the reports relating to the selected company and its problem (e.g. annual reports, income statements, media reports, news)	• Judge real company reports such as annual reports, stock reports, or specific reports relating to the company's origin and destination ports
(7) Use their background knowledge, knowledge of the situation, and previously established conclusions	BI3	Not present, required or assessed in the assignment	Not applicable
Inference	**IN**		
(8) Deduce, and judge deductions	IN1	Understanding the general idea from the various optimisation tools available to the specific details of the problem or model	Understand the 'why' and the 'how' of the problem and the broader picture and represent it into manageable steps for execution
(9) Make, and judge, inductive inferences and arguments (both enumerative induction and best-explanation reasoning)	IN2	Understanding specific details of the problem or model and forming general conclusions (induction)	Understand optimisation function and variables surrounding the problem, sensitivity analysis and results and form general conclusions
(10) Make, and judge, value judgments	IN3	Judging the value of the different models analysed in terms of their solvability, practicality and usefulness to the company analysed	Evaluate and judge the applicability of own solution against other solutions and models applicable to the problem
Advanced clarification	**AC**		
(11) Define terms, and judge definitions	AC1	Defining terms used in the written essay that may not be straightforward or clear to the marker (e.g. 'fuzzy' LP), mainly to report the meaning of a term used in the modelling of the problem; judging definitions where necessary	Define specific terms applicable to the linear programming model used and its component terms, including the meanings of terms used in the context of the problem such as origin and destination ports, fleet and the various variables used
(12) Handle equivocation appropriately	AC2	Not present, required or assessed in the assignment	Not applicable
(13) Attribute and judge unstated assumptions	AC3	Including reasonable claims that can be considered common sense or true about the model, solution or decision	Test and check assumptions made and ensure appropriateness to the model, and adjust accordingly if not met
(14) Think suppositionally	AC4	Not present, required or assessed in the assignment	Not applicable

(*Continued*)

Table 1. Continued.

Critical thinking abilities (Ennis 2015)	Code	Expressed as … (core identifiers)	Paragraphs that … (e.g. using a transhipment optimisation problem)
(15) Deal with fallacy labels	AC5	Not present, required or assessed in the assignment	Not applicable
Auxiliary abilities	**AA**		
(16) Be aware of, and check the quality of, their own thinking (metacognition)	AA1	Not present, required or assessed in the assignment	Not applicable
(17) Deal with things in an orderly manner	AA2	Including step-by-step solutions in building the model and solving the problem; adopting a logical structure to present the written work	Present a logical structure of the formulation and solution of the transshipment problem, including steps in the solutions process, and of the essay
(18) Deal with rhetorical strategies	AA3	Not present, required or assessed in the assignment	Not applicable

Thus we matched and described each of these 11 abilities in the optimisation problem. We recognise, and expect, that a number of factors, such as the disciplinary context, the learning goal of the assignment and the expected abilities in student performance, amongst other factors, will influence future applications of our framework. It is important to note that while there are 18 critical thinking abilities, not all of them apply to each assessment type or discipline. Application to other assignment topics may vary based on what critical thinking abilities students might deploy in responding to an assessment task.

We recognise that the critical thinking literature refers variously to abilities (Glaser 1941; Ennis 1962, 1991), skills (Facione 1990a; Halpern 1998) or competencies (Fisher & Scriven 1997). We also recognise the importance of critical thinking dispositions. However, discussing these differences, and including the dispositions to exercise the skills, is outside the scope of this study. Our objective is to attempt to make progress on the issue of identifying – in a systematic way – the skills students might deploy in responding to an assessment task. We provide a framework for measuring such skills. For want of a better term we shall call this the Critical Thinking Operationalisation Framework (CTOF). We think this will assist others in identifying the above abilities in other student work. This, in turn, will help to identify for students what precisely needs improvement in terms of 'critical thinking' abilities. It will also help staff develop those abilities across teaching, learning and assessment activities that promote those abilities. Figure 1 provides a schematic outline of how the CTOF is used in our study, and usage is expected to vary when applied in other assignment contexts.

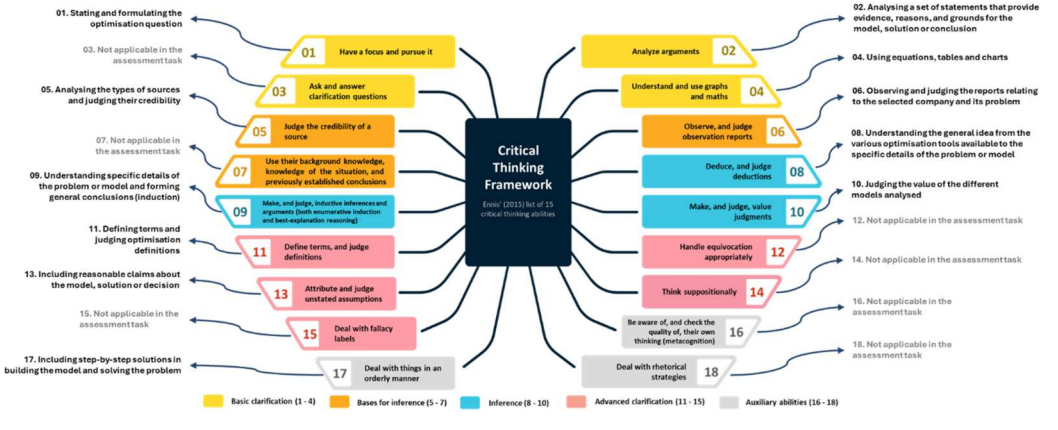

Figure 1. Critical thinking operationalisation framework (based on Ennis' list of 18 critical thinking abilities). Design adapted from PresentationGO.

The assessment and study context

The assessment task used for the study was taken from a masters-level business analysis course which is a core to many master's programs including the Master of Management and Master of International Business offered by a large, research-intensive business school in Australia. A 6000-word group assignment was presented to the students on week 1 of the semester. A response to the task was to be submitted as two written essays: a 2000-word Assignment 1 (A1) due on week 5 and a 4000-word Assignment 2 (A2) due on week 11. There were 12 weeks in the semester, week 12 being devoted to the presentation of team projects. A1 involved a discussion of the company and the linear programming (LP) optimisation problem it is facing. The student teams are asked to search library databases for articles on LP that relate to the type of problem they wish to solve. Typically, LP problems relate to optimisations in industries such as the airline industry, transport, energy, telecommunication and manufacturing. For example, a grocery store may wish to optimise its staff roster, product shelves, storage room or sections of its store, with the goal of efficiently using its resources and considering all the constraints that could yield the best possible outcome (e.g. maximum profit, reduced cost, satisfied customers, etc.). Students were asked explicitly to *critically evaluate* the articles they searched and use the different LP models they came across in those articles.

The instructions for the assignment were as follows: (1) collect, review and synthesise at least 10 academic articles that use LP models to solve an optimisation problem (e.g. cost minimisation, tasks assignment) similar to the problem the teams have selected; (2) analyse the strengths and weaknesses in the models used and propose alternative optimisation solutions; (3) apply mathematical modelling approaches such as LP to formulate and solve the identified optimisation problem from an existing company using real or simulated data; (4) identify the scope and limitations of the solution and provide recommendations for the company to solve its problem and (5) present the findings in class.

In A2, students began to formulate their LP model. Students used tools available to them and attempted to solve the problem. The complexity of A2 required the use of critical thinking abilities outlined in Ennis' list, which makes this assignment amenable to assessment. Students were expected to critically apply and extend their understanding of LP concepts and solve a real current problem that exists in the company of their choice. While this requires problem-solving abilities, it also requires critical thinking abilities. Company data may not be disclosed to the student teams due to the sensitivity and privacy of the information, but students are encouraged to do research, establish their project scope, identify limitations, critically evaluate their model and solutions, and make reasonable assumptions where necessary.

Methods

Data

A total of 152 group assignments were analysed, within an average prescribed word count of 4000 words (±10%). These papers were collected over a six-year period, either in semester 1 or 2 of each year, with the addition of one summer class. As described in the previous section, the assignment explicitly required critical thinking (and other skills such as application, problem-solving, written communication and oral communication, which were outside the scope of this study). Students self-selected the companies or industries they wished to analyse. While two or more teams could select the same company or industry, the assignments were unique, differing in length, presentation, format and evaluation. The way the students discussed the content explicitly required critical thinking, which was also variable between teams.

Each assignment had an average of 43 paragraphs. There were a total of 6545 paragraphs across all assignments, and 319 tables and 851 figures. References were included from the paragraph count and analysis (as per BI1). Tables and figures were excluded from the analysis, although they may be

referred to in a paragraph we analysed. A few assignments included glossaries, and these were excluded as well. We also did not analyse the presentations in week 12, which were mainly 10-minute team presentations together with slides. Where a table included an image from another source, it was counted as a figure. Where equations were included (in text or image formats), they were counted as part of the paragraph. Most of the figures included decision trees, Excel screenshots, schematic representations, model structures, process flows, charts or network diagrams. Out of the 6545 paragraphs, only 3279 were identified as containing the 11 critical thinking abilities listed in Table 1. These paragraphs represented the sample used in this study and therefore the basis for the findings reported in the next section. The study received the appropriate ethics approval to analyse the assignments used in this study.

Data analysis

We adopted Liang and Wang's (2004) method of natural paragraph analysis of case studies (in this case, written assignments) instead of using sentences, or the whole written work, as the unit of analysis. We also believe that the perspectives given within paragraphs are semantically richer than individual sentences, which can be too detailed, and which can lose the overall narrative. We also avoided assessing entire assignments, which can be too broad. We coded each paragraph according to the 11 critical thinking abilities given in our Ennis-inspired framework (see Figure 1). As paragraphs can refer to more than one ability, multiple codes were used. This means that the sum of codes can exceed the number of paragraphs. For example, a paragraph may refer to or include both BC1 and BC2 (within a group of abilities) or BC1 and BI1 (across more than one group). Not all paragraphs attract a code, but considerable care has been taken to re-read these paragraphs and code them accordingly. Our method of coding is described in more detail below.

We also followed Dyer's (2006) approach to identifying author claims (i.e. the students' claims), which she argues is the first step in evaluating arguments. Dyer suggests looking for claims that

Table 2. Coding results for critical thinking abilities.

Critical thinking abilities	Number of paragraphs	%
Basic clarification		
(1) BC1	357	10.9%
(2) BC2	386	11.8%
(3) BC3	NA	–
(4) BC4	520	15.9%
Bases for inference		
(5) BI1	454	13.8%
(6) BI2	473	14.4%
(7) BI3	NA	–
Inference		
(8) IN1	285	8.7%
(9) IN2	457	13.9%
(10) IN3	262	8.0%
Advanced clarification		
(11) AC1	824	25.1%
(12) AC2	NA	–
(13) AC3	668	20.4%
(14) AC4	NA	–
(15) AC5	NA	–
Auxiliary abilities		
(16) AA1	NA	–
(17) AA2	918	28%
(18) AA3	NA	–
Total units/paragraphs		6545
Average units/paragraphs		43
Total CT-related units/paragraphs		3279
Average CT-related units/paragraphs		22

Table 3. Examples of arguments and assertions.

Critical thinking abilities	Paragraph examples
Basic clarification	*This is because the costs and the risks involved in producing expensive blockbusters are too high to tempt the management to go for it*
	Hence, path dependencies have been underestimated in the decision tree
	Thus, the system now-a-days has become more complex in terms of protection schemes and hence validates the need to develop a different algorithm for protection of circuits with UPFC
	The decision variables include the sequence of ports each tanker visits, the loading volume of each type of crude from each port, the loading time at each port, and the ports that each tanker visits
Bases for inference	*Therefore, this paper uses decision tree models to profile technologies and services that can be used by ski resorts in their promotional and advertising strategies for two main customer segments, millennials (less than or equal to 35) and non-millennials (greater than 35)*
	Hence, the decision tree method can be used over a wide array of applications, making it an effective tool for decision making and problem solving
	Overall, the three models have characteristics that are effective for optimising oil and gas distribution in a commercial environment. However, Table 2 shows that each model is strong in different areas and has room for improvement
Inference	*Thus, in the future, ski resorts users can apply the model to fit their own context*
	While the model accurately predicts the direction of change of gold price, it does not provide information about the volume of change of price. This can be misleading and might be a shortcoming in the approach of the model
	Different modelling methods were used to evaluate the feasibility or operation of renewable generation and storage integrated supply and demand systems. All studies aim to reduce cost while maximising economic benefit through optimisation
	In contrast, the previous researches used regression models for exploring the independent risk factors, hence, failed in showing the priority of those risk factors and lacked complex integration of those factors
Advanced clarification	*Hence, the accuracy of the predictive model in this system is vital for its functionality*
	A classification tree is similar to a decision tree such that it represents a DAG, however its nodes and arcs do not have distinct values
	All three models are intended to be used as a decision support tool
	It is therefore only natural that the economic stakes involved in the development of video games are equally high
Auxiliary abilities	*Thus, for optimal results at both stages, integer programming formulas were developed to solve the two sub-problems*
	The hospital needs to allocate 15 nurses with five different expertise levels (classes) to nine shifts in a particular scheduling period of three days at the minimum cost

include inference indicator words such as: '*therefore*', '*thus*', '*in summary*', '*I believe that*', '*in short*', '*the data show that*', '*as a result*', '*in fact*' and synonyms of these words (10, original emphasis). We were careful to ensure that we excluded inference indicator words that were only used grammatically, i.e. without an inference being made (e.g. '*Decision trees are an analytical decision support tool therefore they should be used.*'). We have also included in our search terms the words and phrases *where/whereby* (e.g. when defining each of the variables in an equation), and other related terms such as '*based on this*', '*collectively*', '*arguably*', '*so that*', '*in order to*', '*finally*', '*we conclude*' or '*it can be concluded*', '*then*', '*this implies*', '*in spite of/despite*', and '*as a matter of fact*'. Each of these was used in inference-making. On some occasions, we determined that including *should*, such as in 'the company *should* strongly consider … ' needed to be added to the set of terms. This makes sense in analysing arguments as these statements are consistent with justifications and therefore inference-making concerning recommendations for the company in question. Examples of the use of these words and phrases in the assignments under consideration are provided in Table 3.

To improve coding reliability, intra-rater and inter-rater reliability measures were employed. For intra-rater reliability, a random sample of 10 assignments was evaluated by the same researcher on two separate occasions, and the results did not vary significantly. For inter-rater reliability, two markers independent of the researchers (who were also academics) performed ratings in ten of the abilities across the first four groups of abilities (i.e. excluding the auxiliary abilities [AA] group) on the same sample. *Cohen's K* was calculated to compare their judgments, resulting in substantial

agreements across AC abilities, moderate agreement on BC and IN abilities, and low agreement on BI abilities.

The assignments were analysed for patterns, with specific attention to identifying any or all the core identifiers presented in Table 1. The analysis aimed to answer the following questions: (1) (a) How did the student teams present the company and its problem in text and visual formats, (b) clarify its optimisation problem and (c) analyse their arguments for the solution proposed (i.e. BC abilities)? (2) Did they effectively use all relevant information about the company and its optimisation problem including judging the credibility of their sources (i.e. BI abilities)? (3) Did they make effective logical inferences about their and previous similar LP tools and solutions to support their conclusions (i.e. IN abilities)? (4) Did they define key terms used and made reasonable claims about their model and solution, including their model's limitations and assumptions (i.e. AC abilities)? (5) Were the solution steps reflective of orderly action and consideration about decisions (i.e. AA2 ability) as per our modified version of Ennis' definition of 'critical thinking'? By developing an overarching question for each of the ability categories, this helps to identify how the paragraphs relate to the codes. It also helps to create core identifiers from the patterns observed that reflect each code. We submit that all of these considerations reflect, in practice, and in an assignment context, the use of critical thinking abilities as described by Ennis.

Findings

We begin by presenting the results based on the 11 critical thinking abilities that were present in the assignments. This is followed by some general observations.

Out of the 6545 paragraphs, only 3279 (50.1%) can be taken as representative of the 11 critical thinking abilities outlined by Ennis. Table 2 shows the coding results for the 3279 paragraphs, with the proportion of codes shown in the number of paragraphs coded for each ability and its equivalent percentages. We note again that a paragraph can be classified into more than one code. Unsurprisingly, the essays rank highly on AA2, which could result from the assessment instruction encouraging students to present their solutions in a step-by-step fashion responding directly to the task instructions. This result is perhaps influenced by the many examples of LP solutions presented in the four weeks leading up to the assignment due date. The 'drills' and practical applications across many LP problems showcased during those sessions featured a 'formulaic' way of presenting solutions in a stepwise fashion. It was observed that the students did not depart from this usual presentation nor resort to creative ways of presenting their process in determining solutions. This shows evidence of the procedural setting out of a problem or issue, not critical thinking.

Nonetheless, the paragraphs clearly show critical thinking abilities are being used effectively. Students presented their work with a logical structure, and included a clear formulation of the problem, and details of their solution in clear steps. The company problem was also highlighted at the end of the essay, showing a connection not just to the model and solution but also to company background information and the problem situation under consideration.

Evidence of critical thinking abilities was also observed for AC1, in terms of the use of a precise definition of terms introduced in the essay related to the type and uniqueness of the LP problem that students were attempting to solve. A few students went beyond the concepts covered in the class, and other LP tools and platforms were used in arriving at their solutions. Excel Solver was used exclusively in class, but this was restricted to solving models for a certain number of variables. More powerful tools, such as R, MATLAB or OpenSolver, were required for more complex programs which is also an effective example of deploying critical thinking abilities.

Similarly, AC3 paragraphs effectively communicated the assumptions made by the students and judged them according to their appropriateness to their models. Most of these assumptions pertained to company information that was unavailable. This resulted from a lack of or limited access to company data (e.g., actual work hours of employees or actual profit margins per product line).

We were unable to include considerations such as this in our model. While students were advised to use actual figures as much as possible in their model, in certain circumstances (e.g. commercial in-confidence constraints), they were not permitted to use them. In this case, reasonable assumptions were made.

BC4 was coded extensively for BC abilities. Our analysis of the sample text indicates that students understand clearly the use and value of graphs and maths used to present and solve their problems. This includes tables that students used. Graphical representations were not used as most students opted for Solver or other tools instead of chart tools to display optimisation results. Their equations, sensitivity reports and constraint variables representations were excellent. Slightly lower codes were recorded for BC1 and BC2. The lack of analysis of arguments, i.e. BC2, was mainly related to inadequate and superficial analysis of previous models used to solve similar problems found in the literature. The low result for BC1 was surprising. It was expected that students would have a focus on the company, its problem and solution, and pursue that in their assignment responses. However, some essays did not maintain this focus. This was evidenced by the lack of clear connections between the latter sections of their essay and the initial company background and problem statements in the early parts of the essays.

BI codes were not high either. There was little evidence of judgments on the credibility of sources used, including making judgments on any observation reports used. The IN codes for this group of abilities were also low due to the low observed codes on the BI group of abilities. That is, if the basis for inference was unclear, the inference could be flawed. However, students could not be entirely responsible for this. The assignment design could also influence this, particularly when assignment length would not allow further display of BI1 and BI2 abilities or when a higher proportion of marks was given to solution formulation and execution.

The sample text in Table 3 gives an indication of the different types of claims and assertions representative of the critical thinking abilities displayed by the students according to the four categories BC, BI, AC and AA (see Table 3).

Discussion

Analysis of the sample student work in respect of the proposed framework, the CTOF, reveals that there is some evidence of the use of some critical thinking abilities listed in the framework, but certainly not all were demonstrated. For an assignment purporting to allow students the chance to demonstrate their 'critical evaluation' skills, it appears there was not much evidence of it. But this is not the point of this paper, nor the framework under consideration. The importance of the model lies in removing the vagaries of assessing 'critical thinking' impressionistically and without any systematic method at all – an approach presently used by most management assessors – as far as we can tell – worldwide. The CTOF provides a basis for (a) itemising precisely *what* critical thinking skills are used or not used; (b) adjudicating on the *extent* to which critical thinking abilities are deployed by students (did they 'infer', for example, poorly, well or very well) and (c) on the basis of this, provide a systematic and impartial basis for grading, i.e. in terms of differential achievements of critical thinking among students on given assessment tasks. In other words, it provides a method for assessing 'critical thinking' where before there was none.

From a practical perspective, the findings have a number of wider implications for management educators and educational designers. Making explicit use of critical thinking markers by means of the CTOF – or something like it (we are proposing *a* framework not necessarily *the* framework) – means that educational designers can work alongside management academics in mapping student progress in developing critical thinking skills throughout the semester. Using CTOF-type markers they can examine the learning outcomes in the course and thereby identify the ways in which critical thinking abilities can be embedded in the course to meet intended learning outcomes. This might include the experience in classroom activities as well as what is offered online through the learning management system. In other words, once detailed CTOF mapping is performed, design,

innovation and intervention can follow. This might involve, for example, creating a video tutorial that might make, say, BC4 clearer and easier to understand. Such a learning artefact could be embedded in the course curriculum, thereby addressing learning outcomes related to further developing this critical thinking ability.

Another implication is the leveraging of students' prior experience in problem-solving to assist with developing BI3 skills. These refer to asking and answering clarification questions. It would be useful to draw from students' prior experiences in problem-solving and how those could be helpful in enhancing critical thinking skills in LP contexts. This could be made explicit in course documentation and articulated in student expectations. In addressing IN2 (i.e. make, and judge, inductive inferences and arguments), asking students to explain the rationale behind the use or non-use of certain LP models in their own work and examining why they were used in others, could enrich critical thinking abilities.

For management educators, communication of appropriate critical thinking abilities is key. Students may not necessarily be aware of the many facets of critical thinking (skills and dispositions) and what this looks like in a management context. Indeed, they are never made explicit – possibly because lecturers themselves are unfamiliar with them (Cooper 2024; Paul 2004). Setting class expectations is important in reducing student–instructor misperceptions. It is crucial to set a reasonably high bar in displaying critical thinking as it is a higher-order cognitive skill particularly for masters' students enrolled in this course, and – as we have seen – it is desired by companies and employers as a graduate attribute. Knowing beforehand what is expected can help students align their performance in the course.

Third, existing marking instruments should be reviewed. Do they adequately measure any of the 18 critical thinking abilities of critical thinking espoused in the CTOF model? If not, redesigning assessments may be necessary. For example, if BC2 is an important learning outcome, and a critical thinking ability espoused in the course, it must be first fostered in teaching and learning activities prior to an assessment task being designed to measure and assess such an ability. It cannot, in fairness, be assessed if it is not first (a) described and (b) pre-taught.

Fourth, redesigning assessments may require reconsidering the assessment instruments needed to measure performance. Rubrics might help to clarify what the 18 critical thinking abilities mean for a given task, given a set of performance dimensions and levels of performance achievement. A clear marking or scoring guide aligned to the relevant critical thinking skill(s) being assessed demystifies scores or ratings given for assessment tasks and provides quality feedback to students. Presently, most assessment rubrics completely ignore the assessment of critical thinking skills or make vague, self-referential and circular statements such as: ' … students should demonstrate critical thinking by being "analytical"'. Again, this is probably because 'critical thinking' is understood as a broad, generalised capacity assessed by lecturer 'impressions', and not as a specific set of itemisable skills and dispositions. This is due to ignorance of the critical thinking literature. We have tried to address this neglect.

Fifth, designing teaching and learning activities that foster the development of critical thinking skills is important. These include problem solving activities or simulations which have been found to positively relate to student performance (Lovelace, Eggers, and Dyck 2016). Work is needed on designing such activities that precisely assess the critical thinking skills desired by the instructor.

Lastly, the type of pedagogy and instructional methods adopted influence how critical thinking is inculcated in the curriculum. Snyder and Snyder (2008) contend that misaligned instructional methods are the key reasons that students are not being able to think critically to solve problems in business classrooms. Berkovich (2014) argues that a dialogic type of instructional method, e.g. conversations and meaningful interactions, would be best suited as it could develop not just critical thinking but a number of critical thinking dispositions related to leadership, such as *open-mindedness* or *empathy*. A management pedagogy that teaches students to 'think and feel differently' (Huber and Knights 2022) and to reflect (Tomkins and Ulus 2015) is desirable. Management graduates can thereby make sense of their place in the business school they study at and the community they serve as professionals. This also improves BI3, IN3 and even AAI as they navigate their own

identity in a complex business environment with unique cultural identity and values. A pedagogy that includes developing 'negative capability' (Saggurthi and Thakur 2016) in students may also help to strengthen BI and IN capabilities, as this can teach students to critically deal with uncertainty, complexity and ambiguity in decision-making.

Assessing critical thinking skills in a more systematic way is crucial. Despite assumptions to the contrary, evidence suggests that students are emerging from universities with poor critical thinking skills. Arum and Roksa (2011) used pre – and post-test data from the College Learning Assessment test (CLA+) – a well-validated test that measures critical thinking skills – to track the critical thinking skills gains in 2,322 college students in the USA over a 5-year period (2005–2009). They found that 45% made no significant improvement in their critical thinking skills in the first 2 years of college and 36% made no improvement after an entire 4 years of college. Recent data is no less encouraging. A 2022 OECD report (Van Damme and Zahner 2022) used the CLA+ to pre- and post-test 120,000 students from 6 countries over a 5-year period and noted that critical thinking gains were marginal at best with one-fifth of students performing at the lowest level. 'It is difficult to claim', they note 'that a university qualification reliably signals a level of critical thinking skills expected by the global marketplace' (259). Systematic assessment of critical thinking skills may be a way of reversing this situation.

Limitations, implications and future research

The proposed critical thinking framework is based on a single list of well-known abilities associated with critical thinking (Ennis 2015). It is not suggested, however, that this is the only such set of abilities, nor that they are necessarily the most suitable. Our aim is to trial a methodological framework, the CTOF, using one of the most well-known lists of skills and to see whether a coherent framework and methodology might be devised that can be used as a basis for detailed assessment of 'critical thinking' – an area universally lauded but seldom treated systematically. Our work, in other words, is only a start. Future research might extend this framework by including other discipline-specific critical thinking abilities, and other methodological frameworks, that are more appropriate and refined for business and management contexts, and indeed, in other discipline entirely.

The abilities-paragraphs matching technique, while providing rich source of data analysis, could also benefit from capturing the critical thinking processes that occur between A1 and A2. This includes discussions that might ensue with the lecturer about how teams think through a given management problem and how they determine ways to solve it. The feedback sessions arising from those consultations, including feedback on earlier drafts of assignments – most particularly during model building – can provide additional insights about students' critical thinking abilities. The not applicable greyed-out abilities on Figure 1 (items 3, 7, 12, 14, 15, 16 and 18) could also be purposely included in the assessment artefact in a similar study. This will provide a comprehensive analysis of all associated critical thinking abilities.

Critical thinking is manifested in ways other than through written responses to assessment tasks. It also takes place during teams' consultations with their lecturers and via class presentations and class discussions. This was not included in the study as no data on these forms of assessment is available. In the case of this class, student–lecturer consultations took place regularly and involved iterative processes checking the work of the student teams with respect to their considered solutions and where they might be heading. This too presents an opportunity to assess critical thinking abilities particularly for BC3, BI3, IN1, IN2, IN3, AC2 and AA1. How well can contributions to verbal discussions be assessed in terms of critical thinking? Future research might address this limitation.

Conclusion

Assessing critical thinking skills using a framework derived from a list of critical thinking abilities is a novel application to management education, particularly in the context of business analysis and

management courses. Previous research has looked at assessing various business skills, e.g. writing skills (Calma, Cotronei-Baird, and Chia 2022) and creative thinking (Karunarathne and Calma 2024) but little systematic work has been done on assessing critical thinking skills in management education. Using written assessments in a business analysis course to assess critical thinking skills is a contribution to the literature. Figure 1 illustrates how the framework can be applied. This framework could be adapted to assess critical thinking in other business or higher education fields, other types of assessment or assessable experiences, or displays of student performance in general. The empirical analysis outlined here might be useful for management academics teaching business analysis or similar quantitative-based management subjects. For possibly the first time, they have a method and framework for making explicit what was previously assessed tacitly and superficially – or not at all. However, we recognise that assessing work can be inherently subjective, and we do not propose dismissing subjectivity in marking. Indeed, it is unavoidable and – as it derives from years of professional experience – also highly desirable. What we offer is a framework that provides a complementary tool to identify critical thinking abilities in student work. This is particularly important where identifying critical thinking skills might have been challenging to do previously (e.g. new teaching staff, less experienced of replacement instructors). Our more rigorous approach allows the provision of feedback on how students develop critical thinking more targeted and precise.

The main contributions of this study are as follows: (1) offering a definition of critical thinking in management education; (2) providing a critical thinking framework adapted from Ennis' list of critical thinking abilities; (3) outlining a novel method of analysis of essays to assess the effectiveness of critical thinking abilities displayed by students; (4) providing a theoretical contribution to the assessment of the critical thinking skills of management students and (5) offering practical suggestions for academics in fostering the development of students' critical thinking abilities.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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