Journal of Health Science & Education
An open access journal
eSciRes
JHSE-1-160

Research Article

Does the Participation in Clinical Case Scenario based Clinical Reasoning (CCS CR) Online Teaching/test Influence the Development of Students' CR as Measured by Summative Written Exams?

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Abstract

Background: Clinical reasoning (CR) is an increasingly studied, complex connection between medical knowledge and medical practice; however, it is not traditionally taught formally to medical students. To gain a deeper understanding of the optimal way to approach integrating this into the curriculum, clinical case-based reasoning (CCS CR) formative tests were created based on existing evidence as learning resources and made available on the University of Nottingham's (UoN) online learning platform for medical student access. The students were provided with 4 CCS CR tests in their third year (Clinical phase 1, CP1) and in final year (Clinical phase 3, CP3). **Methodology:** The effectiveness of these resources in improving their knowledge and understanding in CR were measured by increasingly challenging clinically orientated summative assessment. This study explored whether the students who did participate in more CCS CR have significantly greater CR scores in the summative written exam in third year CP1 and in final year CP3 data sets. Data was collected from only the portion of questions that tested CR in the summative written knowledge exam papers for CP1 (2012, 2013, and 2014) and CP3 (2014, 2015, and 2016), and analysed to determine the impact of participation in CCS CR teaching on the development of CR skills. **Results:** There is a significant effect from the use of CCS CR teaching as measured by CR scores in the summative written exams in both Clinical Phase 1 (CP1) and Clinical Phase 3 (CP3) cohorts; however, it is not necessarily a linear relationship. **Discussion and Conclusion:** Participation in CR teaching has a significant impact on the development of CR in medical students, as also suggested by the literature. However, further investigation is required to find an ideal teaching model.

Keywords: Clinical reasoning; Clinical teaching; Clinical learning; Medical education; Medical education research

Abbreviations:

ANOVA: Analysis of Variance; BMedSci: Bachelor of Medical Sciences; CCS: Clinical Case Scenarios; CP1: Clinical Phase 1: the first clinical placement medical students at the University of Nottingham undertake, in the third year for undergraduate students and second year for graduate entry students; CP2: Clinical Phase 2; CP3: Clinical Phase 3: the final clinical placement medical students at the University of Nottingham undertake, in the fifth year for undergraduate students and fourth year for graduate entry students; CR: Clinical Reasoning; CRT: Clinical Reasoning Test; CTT: Classical Test Theory; GEM: Graduate Entry Medicine; GMC: General Medical Council; ID: Item Discrimination index; IRT: Item Response Theory; NCR: Non-Clinical Reasoning; SEM: Standard Error of Measurement; UG: Undergraduate; UoN: University of Nottingham

Background

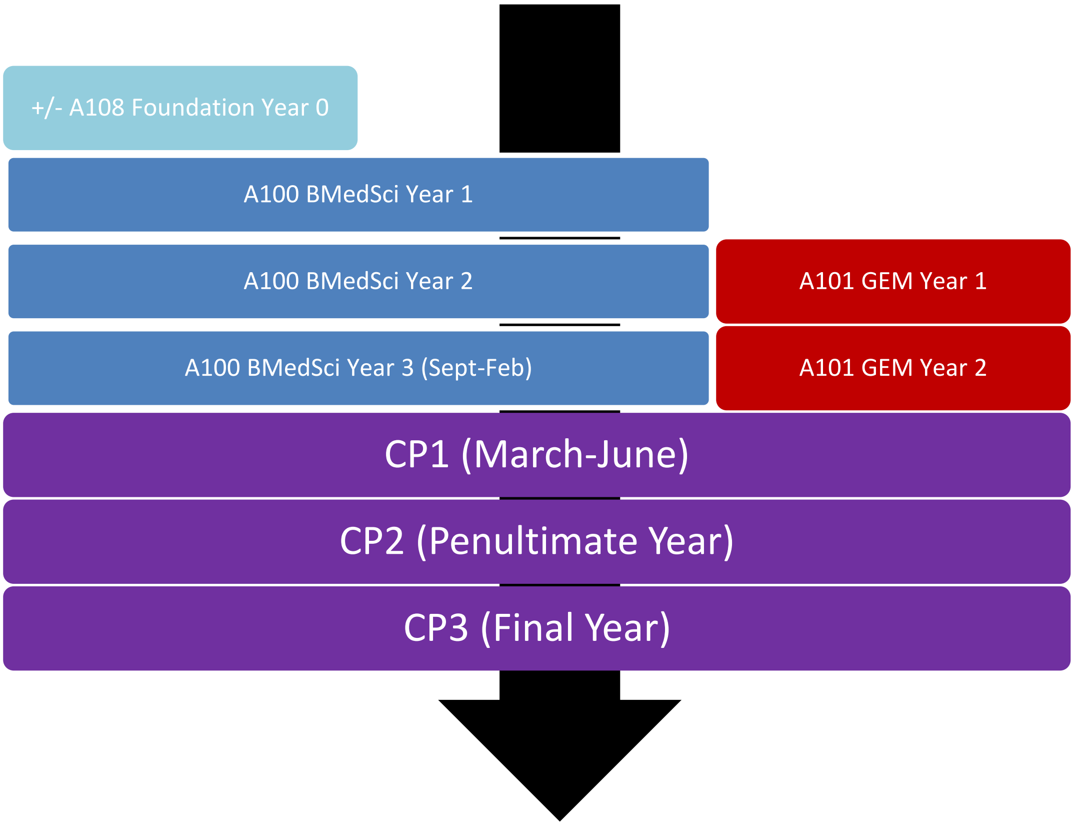
The definition of CR outlines a complex, multidimensional process that aims to recursively analyse and evaluate patient information using both formal and informal strategies.

In medicine, the aim is to reach a diagnosis [1], with CR occupying the bridge between medical knowledge and practice [2].

Traditionally, CR skills are not taught formally, but instead passively gained through experience on undergraduate (UG) clinical placements. Recently, however, the idea that actively teaching CR as part of the UG medical curricula is necessary has gained momentum. Attempting to understand the mental processes behind CR, and utilise that understanding in medical education, is growing in popularity, with the aim of equipping students with adequate diagnostic capabilities [3]. Theories have evolved [4]; current thinking leans towards a unified Dual Process Framework. This encompasses intuition (System 1 thinking) and analysis (System 2 thinking) [5-7]. It is thought that the experienced clinician is familiar enough with the pathologies and presentations within their domain to comfortably and rapidly rely on the former method [2], with an ability to fall back on analysis in more unfamiliar cases [8]. However, novices such as medical students have less clinical experience and therefore limited intuition, hence why they must take a step-wise 'hypothetico-deductive' approach in their reasoning, and the curricula model must reflect this analytical development of their ability [7].

There are multiple ways to translate this to teaching; a popular method is a case-based approach [9] which can integrate basic and clinical science to provide early support in encapsulation and illness script formation. This is used to provide context and form mental links that aid in hypothesis formation and evaluation to reach a diagnosis [2,10]. Previous attempts have received positive feedback [11], with increased satisfaction in both students and teachers, and improvement in time-efficient use with no impact on diagnostic accuracy [2]. Also important is student motivation to learn, which is partly influenced by how the student perceives the course environment [12]. Overall, with regards to CR, clinical cases have been found to be important for aiding the development in student cohorts [2].

Subsequently, a CR theme is being vertically integrated throughout the University of Nottingham (UoN) UG medical degree. As a background, Figure 1 summarises the structure of the UoN medical degree, and how the different pathways interlink to conclude in qualification. Four clinical case scenarios (CCS) were implemented in Clinical Phase 1 (CP1) and Clinical Phase 3 (CP3) as part of the CR curriculum. This study contributes to evaluating the effectiveness of CCS CR in developing students' CR. These were created by the lead author, and delivered as formative CR tests (CRTs) after they were formally validated. A format developed by Da Silva (2013) was used as a basis, as she in turn had designed a CRT by responding to feedback of previous instruments [13]. This separates it from the process used by Schuwirth & van der Vleuton (2004), which based studies on a system that lacked previous evaluation [14].



GEM: Graduate Entry Medicine; BMedSci: Bachelor of Medical Sciences; CP2: Clinical Phase 2

Figure 1: UoN course structure: Paths to medical qualification

CRTs incorporate some features of other tools used to assess CR at the UG level such as a long case-based, theory-driven, flexible instrument that can be used to aid teaching and learning, revision, and assessment of CR at UG level. All the phases contained in the clinical cycle are designed to be covered, from initial presentation to diagnosis, allowing data collection on student performance in all areas.

To ensure the validity and reliability of the CRT cases used for CR assessment, Da Silva (2013) undertook validation processes with positive results [13]; content validity was therefore the only repeated test necessary. The clinical presentations used were selected because they were considered core knowledge, based on both guidelines and the aims of the General Medical Council (GMC) for UG medical curricula outcomes, and realistic scenarios students were likely to encounter once qualified. Expected progression at each stage was taken into account when deciding upon the level of difficulty. For example, CP1 cases were common, typical clinical presentations pitched at an easier level compared to the harder, less prevalent and typical diseases used for the CP3 cases.

Each type of question has its own positives and negatives, which should be accounted for when setting any assessment [14]. Though the CRT made by Da Silva (2013) utilised a range of questions, these CRT cases only employed multiple-choice and short-answers. This was because students who undertook the GEM course were exposed to short-answer questions, whereas BMedSci students were almost entirely tested using multiple-choice hence including both does not give an unfair familiarity advantage to either group. Furthermore, limiting the type of questions used ensures internal consistency, maintaining reliability in the face of validation procedures. The two types of questions selected each assess different skills; multiple-choice questions ask the student to select between several options, whereas short-answer questions require summaries, justifications, result predictions and diagnosis [14].

Model answers were drafted by the case author, and frequently reviewed by five independent clinical experts from different backgrounds (medical education, general practice, medicine, and surgery) who could recommend improvements and minimise speciality-based bias, ensuring valid content in the published version.

The four final CRTs for each cohort were uploaded to UoN's online learning platform, after they had been approved by the universities' committee for CP Course Management. Worldwide, web-based resources are increasingly utilised to support medical education [15]. The CP1 class of 2012 and CP3 class of 2014 were the first cohort to be exposed to these online formative tests, which were programmed to progress and reveal information in sequence and block any attempts to return to previous pages and alter answers.

Figure 2 summarised the general structure of each CRT. Information regarding the patient's details through each of the clinical cycle was progressively revealed, interspersed with regular opportunities for students to outline their thought processes. This was useful for aiding in student preparation for clinical practice as part of medical school aims.

Screen Number	Content
1	Initial presentation.
2	Question to students – summarise patient information; hypothesis and course of action; justification.
3	Question – any further questions to the patient.
4	Answers to some of the questions to the patient, from the previous screen. Question – differential diagnosis.
5	Question – any change to hypothesis formed by student after the extra information. Question – predictions for physical examination findings.
6	Examination findings provided. Question – Revised hypotheses and any investigations required to develop these.
7	Investigation results shown. Question – revised hypotheses.
8	Case summary and diagnosis given.

Figure 2: CRT Generalised Structure, by screen.

Methodology

Data collection and research design

This project is deemed to be service evaluation, and as such the UoN decreed that ethical approval was not required when this study was put forward to their ethics committee. Furthermore, the data has been anonymised and there is no direct involvement of people in this research.

The data discussed has been collated from clinically-orientated, summative knowledge examinations over a three year period. These took place in 2012, 2013, and 2014 for the CP1 category, with CP3 data taken from those papers sat in 2014, 2015, and 2016. As the CP1 students advance through CP2 to CP3 over a two year period, the cohorts progress up – the CP1s in 2012 were the CP3s in 2014, those in CP1 in 2013 sat CP3 papers in 2015, and the 2014 intake of CP1s completed the CP3 examinations in 2016. The total number of students in this period is outlined clearly in Table 1, and ranges from 318 to 351 per cohort.

The CCS CR tests are not mandatory. The purpose of this data collection is to investigate whether medical student completion of Clinical Case Scenarios (CCS) during teaching had an impact on the development of their Clinical Reasoning (CR) abilities, as measured by the marks for the predominantly CR questions in the standardised papers, with a comparison made between the marks of those who did a higher number of CCS CR and those who did not or only did a smaller number of CCS CRTs in each of the three cohorts. This relates to the research question;

"Does the participation in CCS CR on line teaching/test influence on the development of students' CR as measured by summative written exams?"

And thus presents the null hypothesis;

There is no significant effect on CR from the use of CCS CR as measured by CR score in the summative written exams.

Before the exam – Question classification

Each question in each written paper must be classified into having either a CR or non-CR (just knowledge) focus. This is done in standard setting meetings, which are composed of 15-25 people from a range of specialities (for instance; respiratory medicine, gastroenterology, general surgery, etc.) and roles with varying degrees of experience. Consultants, GPs, junior doctors, medical educators, clinical teaching fellows, module leads, and the director of clinical skills represent the range of grades in attendance.

During the review, if a difference of opinion arises with regards to whether a question should be classed as examining CR or not, then two actions can be taken. Firstly, it is mapped against three statements outlined in the GMC's Outcomes for Graduates from Tomorrow's Doctors' – 8c, 8g, 14f [16]. Secondly, Bloom's taxonomy of learning domains is taken into account. Beginning with the simplest and becoming more complex, the major categories of cognitive processes are as follows -

1. Remember
2. Understand
3. Apply
4. Analyse
5. Evaluate
6. Create [17].

To be accepted as fulfilling the criteria to allow classification as CR, the item in question can assess any category from the third to the sixth cognitive process (Apply through to Create). The discrepancy will be discussed until a mutually agreed conclusion has been reached.

Examples of themes for the CR questions used in the final data include: being given a case history and/ or physical findings and asked to select the most likely diagnosis; being given investigation results and being asked to choose the most likely diagnosis and formulate an appropriate treatment plan; being asked to find the matching history or vignette after being given a diagnosis; being given a history and having to choose matching investigation findings.

After the Exam – Psychometric Evaluation

To ensure the examinations remain a high-quality tool for assessment, psychometric analysis is routinely conducted after they have been sat by medical students. Both Classical Test Theory (CTT) and Item Response Theory (IRT) are employed to complete this.

Student-item maps are used to identify questions on the test that prove to be too easy or too difficult. For these problematic items test-score reliability (Cronbach's alpha), standard error of measurement (SEM), and item discrimination index (ID) are used in the evaluation.

Additionally, the items on the knowledge papers are assessed using learning objective as well as frequency and discrimination (U-L) analysis. For each, calculations are preformed to determine the discrimination value (d) and item difficulty (p). Figure 3 outlines how the discrimination value (d) is reached. Items are excluded if they have a d-score <0.15 (translating as low discrimination value for that item) and p-score <0.2 (interpreted as an item with high difficulty). To measure the reliability of those remaining, generalizability is used.

$$\frac{\text{Total number of people with correct answers of the item}}{\text{Total number of people answering item}}$$

Figure 3: Formula used to calculate discrimination value (d).

Internal and external examiners conduct reviews of each of the papers and any comments are discussed before the final scores are made available to students. The marks available for the CP1 and CP3 cohorts investigated are provided in Tables 2 and 3, respectively.

CP1	Students in Cohort	CP3	Students in Cohort
2012	351	2014	335
2013	344	2015	350
2014	327	2016	318

Table 1: Number of students per cohort, for CP1 and CP3.

CP1	Marks			
	CR	NCR	Total	CR % of Total
2012	85	101	186	46
2013	73	112	185	39
2014	116	79	195	59

NCR: Non-Clinical Reasoning

Table 2: Range of marks available for CP1, 2012 – 2014.

CP3	Marks				Marks			
	Paper 1				Paper 2			
	CR	NCR	Total	CR % of Total	CR	NCR	Total	CR % of Total
2014	151	41	192	79	87	83	170	51
2015	85	85	170	50	91	79	170	54
2016	113	57	170	66	98	77	175	56

Table 3: Range of marks available for CP3, paper 1 and paper 2, 2014–2016.

CP1 has one summative knowledge paper whilst CP3 has two papers.

After the exam – Statistical analysis

ANOVAs (analysis of variance) were conducted to determine whether there are significant differences in the CR scores (dependent variable) of the summative written exam across the multiple categories of independent variables; namely, frequencies of participation of CCS (zero to four). There were four separate CCS on offer over the course of each of the independent clinical phases (i.e. four CCSs in CP1 and four different CCSs in CP3). However, the students did not necessarily complete the same number of CCSs during their time in each clinical phase. This analysis determined whether participation in CCS CR teaching has significant effect on the course outcomes measure. Post-hoc tests using Tukey's test are conducted if significant differences are observed to further examine the effects of the independent variables on the dependent variable. A level of significance of 0.05 is used in the analysis. The software facilitating this inspection was IBM© SPSS® Statistics Version 22.

For such parametric statistical tests, a normal distribution in the data collected on the dependent variables is required. To determine whether this was the case, normality testing of those datasets was performed. This was carried out by kurtosis statistics, investigation of skewness and histograms. Kurtosis statistics of 10-20 indicated non-normality, as did skewness statistics >3 [18]. Using this methodology, all datasets were shown to exhibit normality and therefore the parametric statistical analyses can be performed.

Results

The following results of the ANOVA analysis and Tukey's test performed on the two datasets, the CR outcomes of the summative written exams for CP1 and CP3, describe the effect of participating in CCS teaching as part of the medical school curriculum, and whether it significantly influences CR development in students.

CP1 dataset

The ANOVA analysis for the CP1 dataset is displayed in Table 4. It demonstrates that among CCS CR teaching participation frequency differences there is a p-value of less than 0.05. This means there is a significant difference in CR scores in the summative written exam (F (4,666)=41.46, p<0.001) when comparing different uptake rates of CCS.

	Sum of squares	df	Mean square	F	Sig.
Between groups	29799.40	4	7449.85	41.46	0.00*
Within groups	119682.91	666	179.70		
Total	149482.31	670			
*Significant difference at the 0.05 level of significance					

Table 4: ANOVA results of CP1 Dataset; Differences of CR Scored by varying frequencies of CCS participation.

Furthermore, Table 5 display the post-hoc test results that utilise Tukey's test to show the significant differences between the specific number of times the CCS were employed, as measured by the outcomes of the CR questions in the summative knowledge paper. They are summarised as follows:-

- Summative written exam CR scores were significantly greater in those who did not participate in CCS (M = 75.93; SD = 15.05), compared to those who had completed the CCS for a total of two times, (M=66.50; SD=14.69), three times (M=62.42; SD=13.77), and four times (M=60.39; SD=10.51). Respectively, the mean differences are 9.44, 13.52, and 15.55.

- Summative written exam CR scores were significantly greater in those who participated in CCS at a frequency of once (M=76.35; SD=13.68), compared to those who had participated two times, (M=66.50; SD=14.69), three times (M=62.42; SD=13.77) and four times (M=60.39; SD= 10.51). The mean differences are 9.86, 13.94, and 15.97, respectively.

- Summative written exam CR scores were significantly greater in those who participated in CCS at a frequency of twice (M=66.50; SD =14.69), compared to those who had participated four times, (M=60.39; SD=10.51), with the mean difference being 6.11.

(I) Frequency of participation in clinical case scenarios	(J) Frequency of participation in clinical case scenarios	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
0	1	-0.42	1.86	1.00	-5.51	4.67
	2	9.44*	1.90	0.00	4.23	14.64
	3	13.52*	1.94	0.00	8.20	18.84
	4	15.55*	1.87	0.00	10.45	20.65
1	2	9.86*	1.53	0.00	5.66	14.05
	3	13.94*	1.58	0.00	9.60	18.27
	4	15.97*	1.49	0.00	11.90	20.04
2	3	4.08	1.63	0.09	-0.39	8.55
	4	6.11*	1.54	0.00	1.90	10.33
3	4	2.03	1.59	0.71	-2.32	6.38
*The mean difference is significant at the 0.05 level of significance						

Table 5: Post-hoc test results of CP1 Dataset; Differences of CR Scores by varying frequencies of CCS participation.

CP3 dataset

The ANOVA results summarised in Table 6 cover the CP3 dataset outcomes, as measured by the summative written exam CR score. There were significant differences in both the results of Paper 1 and Paper 2 (F (4,663)=2.60, p=0.04, and F (4,663)=3.00, p=0.02, respectively) when different frequencies of CCS CR teaching participation were compared.

This statement is based on p-values being below the 0.05 level of significance.

Additionally, the post-hoc test results shown in Table 7 use Tukey's test to elaborate on the effect that the differences in frequency of participation in the CCS CR teaching curriculum model have on the outcomes, as measured by the CR scores in the summative written exams, as shown below:-

- When comparing the CR scores in Paper 1, those who participated in CCS a total of four times (M=75.36; SD=11.88) obtained significantly more CR marks than those who did not engage with any CCS (M=70.22; SD=13.22). The mean difference in this case was 5.14.
- When comparing the CR scores in Paper 2, those who participated in CCS a total of one time (M=69; SD=9.81) obtained significantly more CR marks than those who did not engage with any CCS (M=66.29; SD=9.90). The mean difference in this case was 3.53.

		Sum of squares	df	Mean square	F	Sig.
CR Score (Paper 1)	Between groups	1696.40	4	424.10	2.60	0.04*
	Within groups	108170.50	663	163.15		
	Total	109866.90	667			
CR Score (Paper 2)	Between groups	1195.59	4	298.90	3.00	0.02*
	Within groups	66085.20	663	99.68		
	Total	67280.80	667			
*Significant difference at the 0.05 level of significance						

Table 6: ANOVA results of CP3 Dataset; Differences of CR Scores by varying frequencies of CCS participation.

						95% Confidence Interval	
Dependent variable	**(I) CCS participation frequency**	**(J) CCS participation frequency**	**Mean difference (I-J)**	**Std. error**	**Sig.**	**Lower Bound**	**Upper Bound**
CR Score (Paper 1)	0	1	-4.14	1.66	0.09	-8.67	0.40
		2	-2.43	1.60	0.55	-6.79	1.93
		3	-3.38	1.67	0.26	-7.94	1.19
		4	-5.14*	1.74	0.03	-9.91	-0.38
	1	2	1.71	1.45	0.76	-2.25	5.66
		3	0.76	1.53	0.99	-3.42	4.94
		4	-1.01	1.61	0.97	-5.40	3.39
	2	3	-0.94	1.46	0.97	-4.94	3.05
		4	-2.71	1.54	0.40	-6.93	1.50
	3	4	-1.77	1.62	0.81	-6.20	2.66
CR Score (Paper 2)	0	1	-3.53*	1.30	0.05	-7.07	0.02
		2	-0.69	1.25	0.98	-4.10	2.72
		3	-2.63	1.31	0.26	-6.20	0.95
		4	-2.96	1.36	0.19	-6.68	0.76
	1	2	2.84	1.13	0.09	-0.25	5.93
		3	0.90	1.20	0.94	-2.37	4.17
		4	0.56	1.26	0.99	-2.87	4.00
	2	3	-1.94	1.14	0.44	-5.06	1.18
		4	-2.28	1.20	0.32	-5.57	1.02
	3	4	-0.34	1.27	1.00	-3.80	3.13
*The mean difference is significant at the 0.05 level of significance							

Table 7: Post-hoc Test results of CP3 Dataset; Differences of CR Scoresby Varying Frequencies of CCS participation.

Discussion

Using the results of the statistical analysis from the CP1 and CP3 datasets, the null hypothesis was rejected. Accordingly, it can be claimed that participation in the CCS CR teaching curriculum model has a significant effect on scores from the CR questions in summative written exams. However, this does not equate to claiming that students who have participated in CCS CR teaching attained higher scores than those who did not partake. Nor does it necessarily mean that cumulative frequency of participation ensures a guaranteed equivalent accumulation of marks in the final paper(s).

With regards to the CP1 dataset, the students who completed one CCS achieved the highest scores. It follows that those who participated in zero, two, three, or four cases attained significantly lower marks in the CR questions. This is not necessarily the immediate rational conclusion one would reach. However, CR is not a skill that can be universally applied with the same outcome, i.e. solving a single clinically-orientated case is a poor predictor of also being able to solve another one. This implies that there is a lot of context-specificity to the use of CR, which is supported by Yazdani's findings, which explicitly outlines context-dependent processes as one of the nine major attributes that contribute to form the medical concept of clinical reasoning [19].

Nonetheless, when examining the marks of CP3 students who completed all four CCS it was found that they scored significantly higher on the CR marks on CP3 Paper 1 when compared to all the other groups. It was the same situation for

CP3 Paper 2, with the exception of those that only completed one CCS. This could be influenced by multiple factors, such as the CR teaching involved with CCS and the comparatively more advanced level of CP3, including the clinical exposure and development of CR mind-set that becomes more evident with experience [2,7] .

Similarly, the current literature also contains evidence supporting the necessity for formal development of CR in medical students, as part of an organised and implemented curriculum. Multiple studies have been undertaken in an attempt to assess the role curriculum has on augmenting CR development, but despite this its effect remains poorly understood [20-23]. Furthermore, with the inconsistent results there remains no single conclusion on the optimal curriculum model with regards to improving CR.

However, given that the findings of this study did support exposure to CR teaching in the form CCS as part of the curriculum model to aid in enhancing the development of student CR ability it is recommended that additional, longitudinal in-depth studies with multiple data collection points are conducted to more thoroughly assess how each specific dimension of CR can be targeted for development in medical student teaching specifically.

Limitations

The data sets that were collected in the process of completing this quantitative research contained multiple differences over the individual cohorts, including; number of students, summative knowledge examination papers, and CR marks as a component of the whole.

The effects of CCSs were a small part of the CR curriculum that could be monitored. Only the relationship between participating CCSs and CR marks was measured as part of this quantitative study. In addition, there were many other factors that might affect these findings, including the fact that the students who participated in these CCS CR teachings were the top students. Also, progression through the course and speciality rotations (including previous experience), case-specific knowledge, should be taken into consideration. The personality of any single student, as well as any stress, illness or fatigue experienced, can affect their emotional intelligence and confidence, which in turn has an impact on the problem solving and critical thinking needed to work through the cases.

There was a maximum of four participating clinical cases (CCSs) to attempt in any one clinical phase; this might not be enough to compare improvement with participation and demonstrate a linear relationship between the two in CR, overall. There could be performance variation on a case-by-case basis, and the context of each could influence outcomes.

Conclusion

In summary, the effect of participating in CCS CR teaching on outcomes in the summative knowledge papers is significant, as shown by the statistical analysis. That there is a connection between CR teaching and development is also supported in the literature. Despite this, there is not a clear relationship between the two and thus more in-depth research is required to finely pinpoint the variables affecting enhancement of CR in medical students, and develop an optimal teaching curriculum model accounting for these.

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Received date: April 29, 2019; **Accepted date:** May 06, 2019; **Published date:** May 07, 2019

Citation: Khin-Htun SY, Brailsford B, Yi NN (2019) Does the Participation in Clinical Case Scenario based Clinical Reasoning (CCS CR) Online Teaching/test Influence the Development of Students' CR as Measured by Summative Written Exams? *J Health Sci Educ* 3(3): 160.

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