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Authors	Maher, Liam;O'Tuathaigh, Colm;Mahon, Ciara
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An assessment of intern doctors' experiences of undergraduate education in electrocardiogram interpretation

Liam Maher [a,b,*], Colm O'Tuathaigh [a], Ciara Mahon [b]

[a] Department of Medicine, University College Cork, Ireland
[b] Department of Cardiology, St Vincent's University Hospital, Dublin, Ireland

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ABSTRACT

Aim: The aim of this study is to assess the adequacy of undergraduate ECG education from the perspective of recent medical graduates.
Methods and methodology: A mixed-methods survey was administered to intern doctors in a large Irish university hospital. A *de novo* survey was developed using established survey design principles and items adapted from validated educational tools and prior ECG education literature. It included Likert-scale items assessing perceptions of undergraduate ECG education, self-rated confidence across seven common ECG patterns, and open-ended questions exploring experiences, barriers, and recommendations. Quantitative data were analysed descriptively, while qualitative responses underwent thematic analysis using the Braun and Clarke framework.
Results: 72 intern doctors participated. Quantitative findings showed variability in perceptions of ECG education quality. Educators were regarded as knowledgeable, but opportunities for active engagement, practice on authentic ECGs, and constructive feedback were limited. Confidence in interpreting common ECG patterns was moderate, with preparedness for clinical practice perceived as inconsistent. Qualitative findings reinforced these results, with participants describing ECG teaching as infrequent, inconsistently delivered, and often disconnected from clinical realities. Stress, low confidence, and limited access to feedback were frequently cited barriers to effective learning.
Conclusion: Although intern doctors value ECG interpretation as a core clinical skill, they feel underprepared by undergraduate teaching. Gaps are evident in the quantity and consistency of instruction, the availability of practice opportunities, and the provision of timely, constructive feedback. Participants expressed a strong preference for small-group, interactive sessions using real-world ECGs with structured feedback, highlighting clear priorities for curricular reform.

Introduction

Electrocardiography (ECG) is a widely used diagnostic tool in clinical medicine, providing a rapid, non-invasive method to assess the electrical activity of the heart. Despite its central role in diagnosing potentially life-threatening cardiac conditions, the proficiency of medical students and hospital doctors in ECG interpretation has been consistently reported as suboptimal, with evidence suggesting a high rate of misinterpretation and missed diagnoses [1–18].

ECG interpretation is particularly relevant for Non-Consultant Hospital Doctors (NCHDs), including intern doctors who represent the most junior grade, who are frequently the first, and sometimes only, clinicians available to interpret ECGs in acute settings. Although senior NCHDs tend to outperform their more junior counterparts in ECG interpretation, their competency levels still often fall short of expectations [2,17–22]. A recent meta-analysis found that even experienced consultant physicians demonstrate variable accuracy in ECG interpretation, highlighting the persistence of this problem despite years of training [19]. This suggests that while experience may improve skills to some extent, gaps in foundational education and lack of opportunities for continued learning may prevent the development of necessary proficiency in ECG interpretation.

Various teaching approaches have been trialled with mixed success. Interactive workshops, integrated ECG courses, and blended learning strategies have been shown to improve both accuracy and learner confidence in the short term [1,5,6,23]. However, the evidence for long-term retention is limited, and most interventions have been evaluated

* Corresponding author at: Department of Medicine, University College Cork, Ireland.
E-mail addresses: 114301261@umail.ucc.ie (L. Maher), c.otuathaigh@umail.ucc.ie (C. O'Tuathaigh), Ciara.mahon@svhg.ie (C. Mahon).

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Table 1
Mixed methods design overview (ECG = Electrocardiogram).

Study Component	Quantitative Strand	Qualitative Strand	Integration
Aim	Measure interns' self-reported confidence & preparedness	Explore interns' experiences of ECG education	Combined to evaluate adequacy of training and improvement needs
Participants	Interns (survey responses, Likert scale items)	Same interns (open-ended survey responses)	Same sample ensures comparability
Data Collection	Likert-scale items; confidence rating of ECG patterns	Open-ended survey questions	Collected concurrently in single survey
Analysis	Descriptive statistics (SPSS)	Thematic analysis (Braun & Clarke) in NVivo	Findings compared and contrasted to generate themes with quantitative context
Outputs	Trends in confidence/ preparedness	Thematic insights into strengths, barriers, and recommendations	Integrated recommendations for curriculum reform

in single institutions with small cohorts, limiting generalisability. Crucially, the literature remains dominated by quantitative outcomes, with little exploration of the learning environment or learners' perspectives on what supports or hinders skill development.

Recent studies have begun to identify potential barriers within undergraduate ECG education. Medical students and NCHDs frequently cite insufficient teaching time, overly didactic lecture formats, limited opportunities for deliberate practice, and a lack of constructive feedback as obstacles to developing proficiency [12,13,24]. Negative attitudes toward ECG interpretation, with some learners describing the task as anxiety-provoking or overly complex, further compound the challenge [24]. These issues suggest that while structural reforms are needed, a better understanding of learners' experiences and perspectives is essential to ensure changes to ECG teaching are both targeted and effective. We therefore sought to evaluate whether intern doctors working in Irish hospitals believe their undergraduate medical education in ECG interpretation adequately prepared them for clinical practice, and how it might be improved.

Methods and methodology

Study design

A mixed-methods survey design was employed as it allowed for the simultaneous collection of a breadth of numeric data on self-perceived competence and confidence alongside detailed, narrative accounts of participants' educational experiences. This study was reported in accordance with the GRAMMS (Good Reporting of A Mixed Methods Study) guideline [25], ensuring transparency in the rationale for using mixed methods, the description of quantitative and qualitative strands, and the integration of findings (Table 1).

Participants and sampling

The target population comprised intern doctors working in one large Irish University Hospital. This cohort had recently completed undergraduate medical education, hence they could provide timely, reflective insights into undergraduate ECG training while minimising recall bias. Paper surveys, comprising both quantitative and qualitative questions, were distributed at weekly intern teaching sessions. Given the mixed-methods and exploratory nature of the study, a formal sample size calculation was not undertaken. Instead, sample size considerations were tailored to each strand. For the quantitative survey items, a target of approximately 70 responses was sought, which is regarded as an acceptable sample size for pilot or feasibility work where the purpose is to test procedures, assess acceptability, and generate stable descriptive estimates rather than to power hypothesis testing [26]. For the qualitative open-ended items, this number also provided adequate breadth of perspectives while remaining feasible for rigorous thematic analysis. The overall intent was to identify trends and learner experiences that could guide future, larger-scale and hypothesis-driven research, rather than to produce definitive statistical inferences.

Survey development

As no validated instrument existed that fully addressed the aims of this study, a *de novo* survey tool was developed. Its design followed established good practice principles for survey creation in health professionals education and drew on multiple sources. Two validated instruments were particularly influential. The DREEM-12[27] (Dundee Ready Education Environment Measure) survey tool was adapted and incorporated for our purposes because several of its items address learners' perceptions of teaching quality and the supportiveness of the learning environment, constructs directly relevant to how participants might evaluate their ECG training experiences. The SEEQ (Student Evaluation of Educational Quality) survey tool items were also modified to assess teaching effectiveness, clarity of instruction, and opportunities for engagement [28]. To ensure relevance to ECG education specifically, additional items were modelled on previously published ECG-focused surveys that examined self-reported confidence, satisfaction with teaching, and perceived preparedness [3,12,15,29,30]. Finally, new questions were written where no suitable precedent existed, particularly to capture qualitative recommendations. Together, these strategies ensured that while the survey instrument was *de novo*, it was firmly grounded in both validated educational measures and the existing ECG education literature.

A multi-stage pretesting process was employed to improve survey tool clarity and validity. The first step involved expert review by three senior educators, including a consultant cardiologist involved in medical education. Cognitive interviews were subsequently conducted with five interns. As a final step, a pilot study was conducted with five additional interns from a nearby hospital to identify any remaining logistical or clarity issues. Responses from pilot study participants were not included in the final analysis. Feedback from each stage was continuously incorporated into survey revisions in consultation with the research supervisors.

The final survey (*Appendix 1*) comprised questions pertaining to current specialty and frequency of ECG interpretation, Likert-scale items on self-perceived competence and preparedness, and a brief self-assessed confidence rating on interpretation of seven common ECG patterns. The Likert-scale items were grouped into six domains reflecting key aspects of undergraduate ECG education identified in the literature and during survey development: (a) educator quality and teaching clarity, (b) engagement and self-development, (c) confidence and preparedness, (d) relevance and understanding, (e) resources, feedback, and practice opportunities, and (f) overall satisfaction. Given the exploratory nature of the study and the modest sample size, formal psychometric testing of internal consistency for the Likert domains was not undertaken. Open-ended questions were also included to allow participants to describe, in their own words, the resources they had used, occasions when they felt underprepared, barriers to learning ECG interpretation, and suggestions for improvement.

Data management and protection, ethical considerations

Participation was entirely voluntary. No identifiable data was collected on the questionnaire itself, and participants were informed from the outset of their right to withdraw at any time. Ethical approval

Table 2
Specialty distribution and ECG interpretation frequency of study participants.

Current Specialty	Count (Percentage)	Frequency of ECG Interpretation	Count (Percentage)
Internal medicine	25 (34.7)	Daily	9 (12.5)
Surgery	16 (22.2)	Several times per week	18 (25)
Intensive care	1 (1.4)	Weekly	11 (15.3)
General practice	1 (1.4)	Monthly or less	3 (4.2)
Not specified	29 (40.3)	Not specified	31 (43)

was granted by the St. Vincent's Hospital Group Research and Ethics Committee in March 2025. Completed paper surveys were manually transcribed into a password-protected SPSS file (SPSS Statistics, version 24, *IBM Corporation,* NY, USA), stored on a password-secured computer. Data was retained only as long as necessary to complete the research project and was then permanently deleted in accordance with institutional data policies.

Data analysis

Participant characteristics were summarised as counts and percentages. Likert-scale responses were analysed as frequency distributions and expressed as percentages. Self-reported confidence in interpreting seven ECG patterns were also expressed as percentages. Quantitative data were analysed in SPSS. Free-text responses were analysed using thematic analysis, following the six-phase framework established by Braun and Clarke [31]. NVivo (version 15, *Lumivero*, Denver, USA) was used to assist with qualitative data management and coding.

A third-party reviewer was invited to independently code a subset of free-text responses and review theme development for consistency [32]. Integration of quantitative and qualitative strands was achieved through a convergent design with narrative merging, whereby findings from both datasets were amalgamated to provide complementary perspectives [33]. For the quantitative element, transparency in analysis and explicit reporting of raw response frequencies supports reproducibility and objective interpretation.

Results

Participant characteristics

A total of 72 interns participated in the mixed methods study. 100 interns had been approached, yielding a response rate of 72%. The participants included representation from those currently working a rotation in internal medicine, surgery, intensive care, and general practice, with their respective frequencies outlined in Table 2. The reported frequency of being required to interpret an ECG in their current role is also outlined in Table 2.

Quantitative findings: perceptions of undergraduate ECG education

Likert-scale questions explored participants' personal experiences and perceptions of undergraduate ECG Education in different domains (Fig. 1).

Educator quality and teaching clarity

Most participants reported that their educators were knowledgeable, with 51.4% ($n = 37$) strongly agreeing and 38.9% ($n = 28$) agreeing with this statement. Regarding clarity of explanations, 19.4% ($n = 14$) strongly agreed and 33.3% ($n = 24$) agreed that ECG concepts were explained clearly, while 8.3% ($n = 6$) disagreed and 6.9% ($n = 5$) strongly disagreed. In terms of the use of relevant clinical examples,

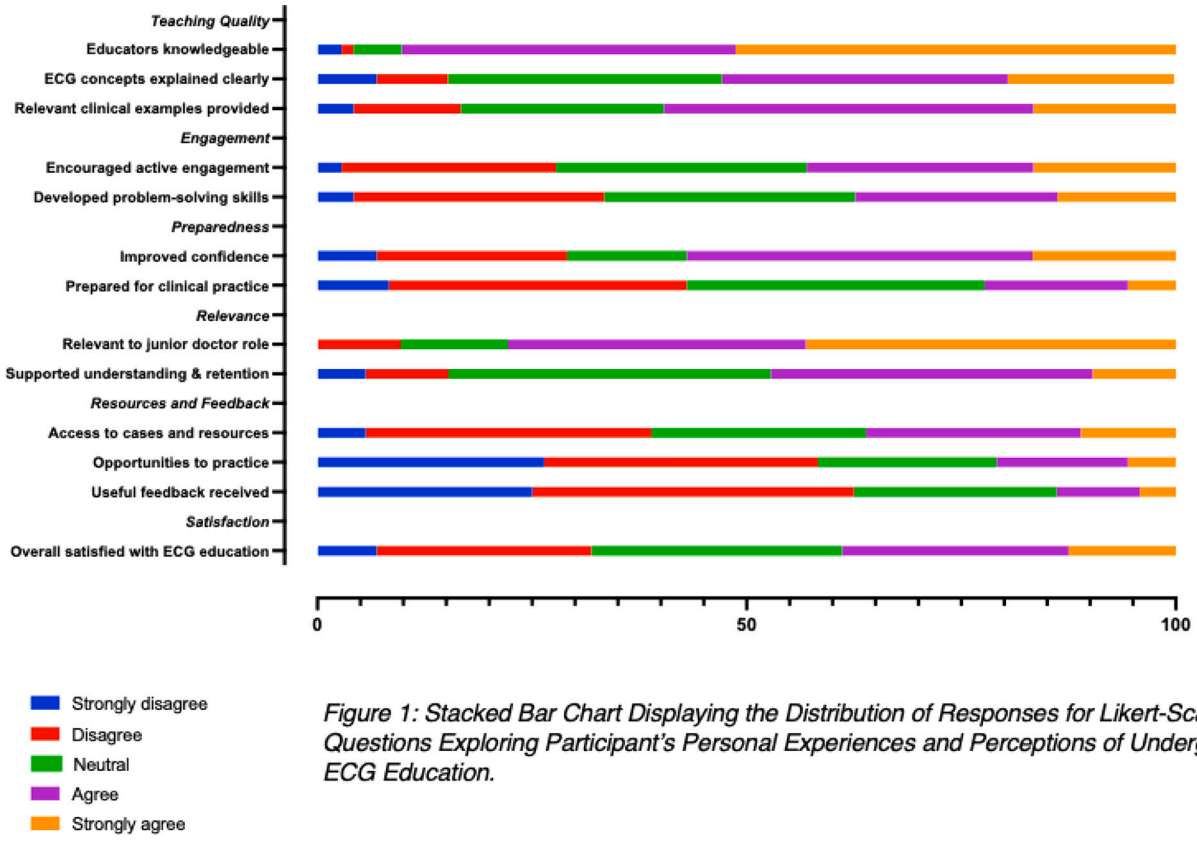


Figure 1: Stacked Bar Chart Displaying the Distribution of Responses for Likert-Scale Questions Exploring Participant's Personal Experiences and Perceptions of Undergraduate ECG Education.

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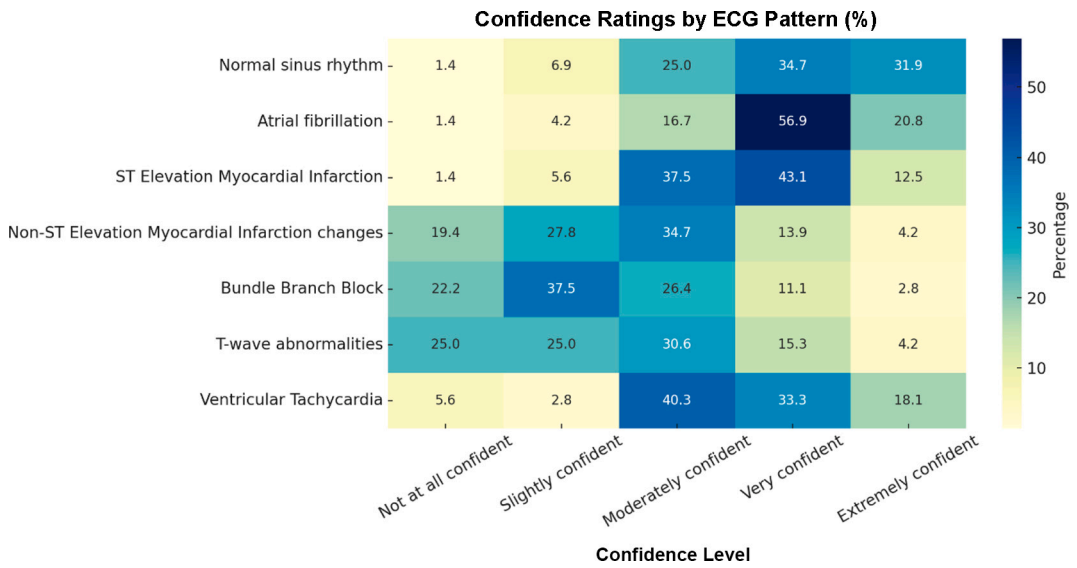


Fig. 2. Heatmap displaying the distribution of confidence scores across the seven common ECG patterns (n = 72).

16.7% ($n = 12$) strongly agreed and 43.1% ($n = 31$) agreed that relevant examples were provided, whereas 12.5% ($n = 9$) disagreed.

Engagement and self-development

When asked whether ECG teaching encouraged active engagement, 29.2% ($n = 21$) remained neutral, while only 26.4% ($n = 19$) agreed and 16.7% (n = 12) strongly agreed. A similar trend was seen for problem-solving skill development, with 29.2% ($n = 21$) neutral, and fewer than 24% agreeing and fewer than 14% strongly agreeing. Notably, 28–33% of participants disagreed or strongly disagreed with these statements.

Confidence and preparedness

For the statement that ECG teaching improved confidence, 16.7% ($n = 12$) strongly agreed and 40.3% ($n = 29$) agreed, while 29% (n = 21) disagreed or strongly disagreed. Furthermore, only 5.6% ($n = 4$) strongly agreed they felt well-prepared to interpret ECGs in clinical practice, with 34.7% ($n = 25$) selecting agree, and over 43% ($n = 31$) expressing neutral or negative responses. Additionally, over 95% ($n = 69$) of respondents reported having had personal experience of feeling underprepared when asked to interpret an ECG in a clinical setting.

Participants were also asked about preferred formats for further ECG teaching. Over 95% supported the introduction of additional structured ECG teaching sessions. Two thirds favoured small-group teaching, approximately half favoured case-based or simulation-based sessions, one quarter favoured an online interactive course, one sixth suggested bedside teaching, and one seventh suggested an app-based learning module.

Relevance and understanding

When asked whether ECG teaching was relevant to their role as a junior doctor, 43.1% ($n = 31$) strongly agreed, with an additional 34.7% ($n = 25$) agreeing. In terms of the teaching enabling them to understand and retain the ECG skills taught, 37.5% ($n = 27$) agreed and 9.7% ($n = 7$) strongly agreed, although a notable 9.7% (n = 7) disagreed and 5.6% ($n = 4$) strongly disagreed.

Resources, feedback, and practice opportunities

Access to cases and teaching resources was reported as sufficient by 11.1% ($n = 8$) who strongly agreed and 25% ($n = 18$) who agreed, while 33.3% ($n = 24$) disagreed. Opportunities to practise interpreting real patient ECGs were reported as limited: 26.4% ($n = 19$) strongly disagreed and 31.9% ($n = 23$) disagreed that they had ample opportunities. For feedback, 4.2% ($n = 3$) strongly agreed and 9.7% ($n = 7$) agreed that useful feedback had been provided, while 25% (n = 18) strongly disagreed and 37.5% ($n = 27$) disagreed.

Overall satisfaction

Overall satisfaction with undergraduate ECG education was reported by 12.5% ($n = 9$) who strongly agreed and 26.4% ($n = 19$) who agreed that they were satisfied. A further 29.2% ($n = 21$) selected a neutral response, while 31.9% ($n = 23$) reported dissatisfaction.

Quantitative findings: ECG Confidence assessment

Participants were asked to rate their confidence in interpreting seven common and clinically important ECG patterns using a five-point Likert Scale ranging from 1: 'Not at all Confident' to 5: 'Extremely Confident'. The median score was 3 ('Moderately Confident'), with interquartile range from 2 to 4 (Fig. 2).

Higher confidence patterns

Confidence was generally highest for Normal Sinus Rhythm, Atrial Fibrillation, Ventricular Tachycardia, and ST Elevation Myocardial Infarction (STEMI). For Normal Sinus Rhythm, 48.6% ($n = 35$) reported being 'Very Confident' or 'Extremely Confident', while only 1.4% ($n = 1$) reported being 'Not at all Confident'. For Ventricular Tachycardia, 51.4% ($n = 37$) reported being 'Very Confident' or 'Extremely Confident', while only 8.3% ($n = 6$) reported low confidence ('Not at all Confident' or 'Slightly Confident'). Confidence was strongest for Atrial Fibrillation, with 77.8% ($n = 56$) selecting either 'Very Confident' or 'Extremely Confident', the highest across all patterns. Participants also generally responded favourably to identifying STEMI, with 55.6% ($n = 40$) in the top two confidence categories and only 1.4% ($n = 1$) expressing no confidence.

Lower confidence patterns

Participants expressed the least confidence in identifying Non-ST Elevation Myocardial Infarction (NSTEMI) changes, T-wave abnormalities and Bundle Branch Block. For NSTEMI changes, only 18.1% ($n = 13$) were either very or extremely confident, 47.2% ($n = 34$) were 'Moderately Confident', and another 47.2% (n = 34) reported lower confidence. For T-wave abnormalities, only 19.4% ($n = 14$) reported being 'Very Confident' or 'Extremely Confident', while 50% ($n = 36$) reported being 'Not at all Confident' or 'Slightly Confident'. For Bundle Branch Block, confidence was lowest overall: only 11.1% ($n = 8$)

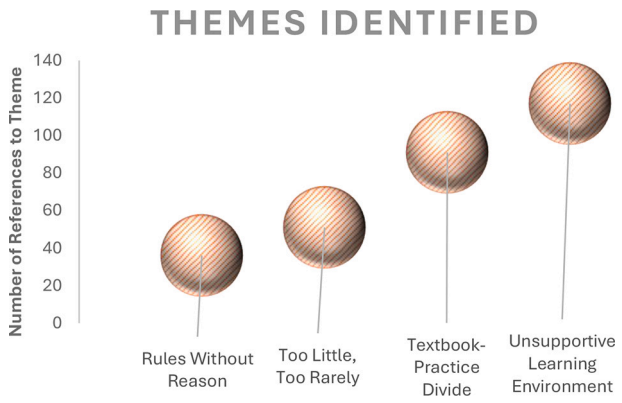


Fig. 3. Bubble Chart Depicting Overarching Themes Identified in Thematic Analysis and the Frequency of their Reference in all Free-Text Responses.

reported being in the top two categories, while 59.7% ($n = 43$) expressed low confidence.

Qualitative findings

A total of 72 respondents provided written responses to at least one open-ended question. Four overarching themes were identified:'Rules Without Reason', 'Too Little, Too Rarely', 'Textbook-Practice Divide', and 'Unsupportive Learning Environment'. The frequency with which each of these themes is referenced is depicted visually in Fig. 3, although frequency alone does not fully capture the depth or importance of participants' perspectives.

Theme 1: Too Little, Too Rarely.

Many participants commented on the limited volume and inconsistent nature of ECG instruction during their undergraduate training:

" Not enough practice until already in clinical setting" (Question 5c, respondent 34),

"Inadequate amount of time spent teaching ECG interpretation to students. Not relevant for medical school exams so not high yield learning" (Question 5c, respondent 38),

"Large amount of time between ECG teaching" (Question 5c respondent 63).

Participants emphasised that ECG interpretation was often expected as a baseline skill in clinical practice, but not prioritised in the syllabus, with the onus often falling on them to learn themselves as best as they could:

"Need to understand the concepts to actually understand ECGs and we don't have enough supervision/ teaching with real examples" (Question 5c, respondent 58),

"It's such a shame that we don't get more proper teaching in it. I don't feel confident interpreting ECGs and now I am an intern. I did try to study it during college but there's only so much you can do on your own" (Question 6, respondent 18),

"Most of it we are expected to learn ourselves" (Question 5c, respondent 68).

There was a clear signal of learners calling for:

"More regular exposure, more review tutorials" (Question 5d, respondent 63),

"Incorporate more teachings throughout the years" (Question 5d, respondent 59),

"Regular systematic common ECG pattern interpretation sessions" (Question 5d, respondent 53).

Theme 2: An Unsupportive Learning Environment.

The setting and atmosphere in which ECG education occurred was a recurring theme in the qualitative responses. Participants described both logistical and emotional barriers to learning ECG interpretation effectively.

Some reported that teaching was largely delivered in didactic formats that were not well-suited to skill acquisition:

"Often in lectures they say they'll give us 'a few minutes' to interpret the ECG on the screen. But there will be one person in the class who shouts out the answer before I've had time to properly look at it and then the lecturer moves on" (Question 5b, respondent 68),

"I have found lecturers don't really explain the anatomy of the heart, the blood vessels and the direction of conduction and how this presents as waves on the ECG. If we haven't be taught what's normal/how normal sinus rhythm is created in the heart it is difficult to understand when things go wrong" (Question 5c, respondent 25),

"Requires practice and often only one lecture given and deemed satisfactory" (Question 5c, respondent 46).

There was a strong preference for in-person smaller group teaching sessions to facilitate questions as well as feedback after attempts at interpreting real examples:

"Small group teaching sessions to solidify our knowledge and work through real practice examples after we learn the fundamentals would be extremely good for students and incoming interns" (Question 5d respondent 58),

"Teaching on ward rounds or in other real-life situations would be very helpful" (Question 5d, respondent 27),

"More small group tutorials and more interactive teaching" (Question 5d, respondent 62),

"More interactive teaching with more constructive feedback and real-life examples" (Question 5d, respondent 67).

"In-person formal teaching as we get to ask questions" (Question 4b, respondent 58),

"In-person formal teaching to help answer the questions/explain more in-depth and help me to engage more" (Question 4b, respondent 24).

Others expressed that a lack of feedback and follow-up assessment or teaching hindered their progress:

"Getting proper feedback when you escalate ECGs would be helpful" (Question 5c, respondent 50),

"Need proper feedback from senior colleagues" (Question 5d, respondent 50),

"I was handed an ECG and asked to interpret, no clinical context of the patient given at all. Was not able to determine the abnormal finding and was just told the finding without any feedback on my interpretation" (Question 5b, respondent 56).

There was also mention of emotional factors such as stress, low confidence, or hesitation to seek help when attempting to interpret an ECG:

"Feeling silly calling the cardiology registrar who is very busy" (Question 5c, respondent 32),

"I've been made to feel stupid by peers and some doctors and so I lost my confidence and desire to learn ECG's" (Question 5c, respondent 66),

"This is so important. I think we are all scared to miss an MI when on call" (Question 6, respondent 25).

A significant number of respondents reported having had an experience of feeling underprepared when asked to interpret an ECG in a clinical setting, with associated emotions including:

"Embarrassing" (Question 5b, respondent 43),

"Worried I will miss ECG abnormalities. I don't feel confident enough" (Question 5b, respondent 15),

"Stressful scenario, complex ECG needed interpretation, no senior help at the time, unsure of next steps" (Question 5b, respondent 29).

The learning environment was also described as highly variable depending on clinical placement:

"Less formal teaching time if with busy doctors" (Question 5c, respondent 72).

Theme 3: Rules Without Reason.

This theme relates to participants' experiences of how the ECG content was taught, particularly whether they found the explanations clear, structured, and appropriate for their learning level.

Many participants noted that the material was either overly simplified or poorly explained, leading to lasting confusion:

"The topic is not explained well", (Question 5c, respondent 26),

"Difficulty with core concepts and volume to remember" (Question 5c, respondent 52),

"Sometimes a lot being thrown at us at once" (Question 5c, respondent 69),

"Biggest challenge is actually understanding as opposed to learning to present to consultants or for exams" (Question 5c, respondent 41).

Several reflected that although they were exposed to ECGs in theory, the quality of instruction was insufficient to gain confidence in practical interpretation:

"Difficult to retain without real life examples and consistency" (Question 5c, respondent 67),

"Not enough pattern recognition repetition to become confident and develop muscle memory" (Question 5c, respondent 15),

"Not always understanding which each part of the ECG represents i.e. what's actually happening in the heart" (Question 5c, respondent 54).

Others described being taught checklists or simplified rules without being guided through the underlying concepts:

"Rarely explained in an intuitive way so one is reliant on rote learning/ pattern recognition rather than understanding" (Question 5c, respondent 48).

Participants especially valued learning resources that either provided a "*good explanation of foundational concepts*" *(Question 4b, respondent 48)* and/or were felt "*most applicable to real-life practice" (Question 4b, respondent 20)*. The most helpful resources for learning ECG interpretation frequently cited were in-person teaching sessions including practice on authentic ECGs with the opportunity for real-time feedback, popular websites such as *YouTube* and '*Life in the Fast Lane'* which provided *"clear, concise, helpful examples*" (*Question 4b, respondent 21*) which in turn helped develop skills for *"good understanding and comprehensive analysis*" (*Question 4b, respondent 11*), and the well-known textbook '*ECG Made Easy'*.

Theme 4: The Textbook-Practice Divide.

Many participants discussed the disconnect between their undergraduate ECG teaching and the realities of clinical practice which they discover once they begin working as interns:

"Often, examples given in teaching are perfectly clear 'textbook' examples, but in reality, real patient ECGs can be more nuanced to interpret and have clinical context" (Question 5c, respondent 29),

"Real Life ECGs tend to not look as clear or have artefacts and as a result are difficult to interpret" (Question 5c, respondent 30),

"Lack of exposure into just how ambiguous real-life ECGs can be" (Question 5c, respondent 37).

Others highlighted that real clinical cases were more effective in developing their skills than formal, textbook ECG-based teaching:

"Not enough practice and guidance in the clinical setting with real patient ECGs" (Question 5c, respondent 55),

"Move ECG teaching to the wards. Focused history and exam on patients and then give the student/NCHD the ECG, ask them to interpret and how confident are they with the findings on ECG in context of their clinical findings" (Question 5d, respondent 56),

"Use more ECGs that are found in hospital settings, ones that are not as obvious as some you will find in a book. Starting with easy examples and building up in difficulty" (Question 5d, respondent 4).

Several respondents explicitly stated that ECG education should be better aligned with clinical situations, to better reflect its importance in day-to-day decision-making:

"ECG teaching is separated from real patients. Students must be interpreting within actual clinical contexts. The context surrounding the patient can increase/decrease clinical suspicion and confidence in the presence/ absence of certain findings" (Question 5c, respondent 56),

"Not enough interpreting ECGs on the ward and not enough inclusion of medical students by the team" (Question 5c, respondent 63).

Participants proposed a number of suggestions to make teaching more clinically relevant and effective, including peer-to-peer teaching, incorporating examples of ECGs they have already personally come across, and employing simulation:

"Simulation teaching in low-stakes environment so we can learn safely" (Question 5d, respondent 29),

"More ECG practice in person using for example ECGs from on call and going through them step by step" (Question 5d, respondent 35),

"NCHDs to teach ECG interpretation in order to learn" (Question 5d, respondent 43),

"Guidance from seniors is helpful when you have real-life examples" (Question 4b, respondent 25).

Discussion

This study explored whether intern doctors felt their undergraduate ECG education had adequately prepared them for clinical practice, and how it might be improved. Within this single-institution cohort of intern doctors, our integrated quantitative and qualitative findings indicate that while participants consistently valued ECG interpretation as a critical clinical skill, their preparation was perceived as inadequate. Teaching was limited, inconsistently delivered, and poorly aligned with clinical demands.

A recurrent issue was the predominant employment of large-group, didactic lectures for ECG teaching, which participants felt were poorly suited to skill development. In contrast, they expressed a strong preference for small-group, case-based workshops using real-world ECGs, guided by peers or seniors in a format that encouraged active participation and discussion. This preference aligns with the outcomes of numerous previous studies [13,15,23]. This reinforces the argument that ECG interpretation, a practice-based skill, requires educational interventions that go beyond didactic transfer of information.

Low self-reported confidence and preparedness were also noticeable features in our responses. Quantitatively, average confidence ratings across seven common ECG patterns did not exceed the moderate range, and qualitatively, participants described stress and anxiety when asked to interpret ECGs in clinical practice. These findings mirror those of multiple studies across various continents, which have consistently reported low confidence among medical students and NCHDs [3,7,12]. Prior studies of both undergraduate and postgraduate cohorts have also demonstrated low accuracy in ECG interpretation [4,9]. However, it is important to emphasise that the present study assessed perceived confidence rather than objective diagnostic accuracy. Confidence and competence do not always correlate, and learners may either underestimate or overestimate their true ability. Therefore, caution is required when extrapolating these findings, as reported confidence should not be assumed to reflect actual clinical competence. The findings should therefore be interpreted as reflecting perceptions of preparedness rather than direct measures of ECG interpretation performance. Beyond technical competence, previous qualitative work has shown that low confidence in ECG interpretation leads to avoidance behaviours and negative attitudes toward ECGs [13,24], a pattern reflected by some participants in this study, who frequently linked ECG interpretation with anxiety and uncertainty rather than with confidence.

Despite these challenges, participants in this study consistently emphasised the importance of ECG interpretation, recognising it as a core skill for clinical practice. The frustration lay not in undervaluing ECGs but in perceiving that undergraduate teaching had not equipped them sufficiently. Similar findings have been reported internationally, with medical students and interns describing ECG interpretation as central to their responsibilities yet feeling underprepared to perform it competently [3,10,12].

Another concern was the perception that the quantity and consistency of ECG teaching during undergraduate education were insufficient. Several participants described too few scheduled teaching sessions, delivered unevenly across rotations, with long gaps between exposures. This reflects international findings [1,13]. When considered along with participants' recognition of ECG relevance, this finding emphasises a critical deficit. ECG education is not yet delivered in

proportion to its clinical value.

Limited opportunities for deliberate practice were also highlighted. Participants felt that ECG interpretation was taught in brief, isolated encounters with little chance for consolidation. Yet evidence certainly suggests that practice volume is essential. Repeated case exposure supports pattern recognition, diagnostic speed, and accuracy [2,7,10]. Consistent with the central role of real-world ECG interpretation practice, participants' qualitative accounts strongly emphasised the importance of feedback. Immediate, specific guidance from instructors was repeatedly described as one of the most helpful aspects of ECG learning yet was noted to be inconsistently available. Broader medical education literature likewise affirms that feedback is one of the most powerful tools for improving competence, particularly in complex interpretative skills [34,35]. In ECG education specifically, structured feedback has been shown to improve both confidence and accuracy compared with unsupervised practice [1,6]. The relative absence of feedback in participants' accounts therefore represents a missed educational opportunity.

Finally, participants described a disconnect between undergraduate ECG teaching and the ECGs encountered in practice. Teaching often relied on simplified, textbook examples without clinical context, while clinical work demanded interpretation of more complex ECGs in high-stakes scenarios. This sentiment is echoed in the international literature [4,5,13]. Alignment between undergraduate module content and the reality of practice is critical if students are to feel prepared for clinical duties.

Limitations

Several limitations must be acknowledged. The study was conducted at a single institution. As such, the findings may not be fully generalisable to other institutions or to international contexts with different academic structures. Similarly, the participants were limited to interns only and did not include NCHDs at more advanced stages of training. While this population was selected intentionally because of their proximity to undergraduate education, extrapolating the findings to postgraduate trainees more broadly should be approached with caution. Participants were recruited during scheduled intern teaching sessions, which may introduce selection bias, as interns who attended these sessions or who chose to participate may differ systematically from those who did not. The study did not collect sufficient demographic detail to allow for meaningful subgroup analyses. A further limitation was that the study relied on self-reported confidence ratings rather than objective measures of competence in ECG interpretation. While confidence is an important educational outcome in its own right, it does not always correlate with diagnostic accuracy. Accordingly, the findings should be interpreted with caution, as they reflect perceived rather than objectively measured competence.

From a methodological perspective, the use of a non-validated survey tool represents a limitation. Although rigorous steps were taken to enhance face and content validity, formal psychometric validation – including assessment of reliability and construct validity - was not undertaken and would be required to strengthen the robustness and reproducibility of the tool in future studies. The relatively modest sample size also limits the robustness and generalisability of the quantitative analyses, though the qualitative richness partially compensates for this. While additional inferential analyses could be informative, the study was not powered for hypothesis testing and such analyses would be unlikely to yield robust conclusions. Finally, the cross-sectional design precludes assessment of how confidence and competence evolve over time, or how different educational interventions may impact these trajectories.

Implications for practice and research

The findings of this study suggest clear priorities for strengthening ECG education. At the level of undergraduate training, reforms are needed to move beyond large, lecture-based formats and to instead adopt small-group, interactive ECG teaching sessions. These should prioritise the use of authentic, clinically contextualised ECGs allowing learners to practice diagnostic reasoning in scenarios that mirror real clinical demands. Learners should be provided with structured and repeated opportunities for deliberate practice, delivered at regular intervals and made accessible across all clinical placements to ensure consistency of exposure. Crucially, such sessions should incorporate timely, constructive, and non-judgemental feedback.

This study also highlights important directions for future research. Firstly, once such undergraduate education reforms are enacted, similar mixed-methods studies should be undertaken to evaluate their impact on learner confidence, competence, and perceived preparedness for clinical practice. Secondly, longitudinal research would be valuable in tracking how confidence and competence evolve from undergraduate training through the early postgraduate years, and in identifying which educational strategies have the most sustained impact. Finally, qualitative work exploring the perspectives of faculty and clinical supervisors could provide complementary insights into barriers and facilitators of effective ECG education.

Conclusion

This mixed-methods study indicates that while intern doctors consistently recognise ECG interpretation as a core clinical skill, their undergraduate preparation is perceived as inadequate as regards teaching methods, quantity and consistency of instruction, practice opportunities, and feedback. Confidence in interpreting common ECG patterns is modest. These challenges are compounded by a disconnect between the simplified ECGs encountered in training and the complex ECGs faced in clinical practice. The study contributes new insights by combining quantitative measures with rich qualitative accounts, highlighting not only persistent deficits but also the emotional and experiential dimensions of ECG learning. Its implications are evident; ECG education should move toward small-group, interactive teaching with authentic clinical cases, delivered at regular intervals and accompanied by constructive feedback.

Credit authorship contribution statement

Liam Maher: Writing – review & editing, Writing – original draft, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Colm O'Tuathaigh:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **Ciara Mahon:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

The authors have no conflicts of interest to declare.

Appendix 1

Survey: An Assessment of Intern Doctors' Experiences of Undergraduate Education in ECG Interpretation

The following questions ask about your experiences learning ECG interpretation during medical school. Please answer based on your personal experience. There are no right or wrong answers.

Section 1: About You (*circle most appropriate answer)*

1. What specialty are you currently working in?
   Medicine Surgery ED GP Other…….
2. How often do you need to interpret an ECG in your current role?
   Daily Several times a week Weekly Monthly or less.

Section 2: Personal experience and Perceptions of your ECG Education.
(tick most appropriate answer)
Please indicate how much you agree or disagree with the following statements (from 1: strongly disagree to 5: strongly agree)

#	Statement	1	2	3	4	5
1	The educators who taught ECG interpretation were knowledgeable.	○	○	○	○	○
2	The educators explained ECG concepts clearly.	○	○	○	○	○
3	The educators provided relevant clinical examples to help explain ECG interpretation.	○	○	○	○	○
4	The ECG teaching encouraged me to engage actively in the learning process.	○	○	○	○	○
5	The ECG teaching helped me develop problem-solving skills related to ECG interpretation.	○	○	○	○	○
6	The ECG teaching improved my confidence in interpreting ECGs.	○	○	○	○	○
7	I feel well prepared to interpret ECGs independently in clinical practice.	○	○	○	○	○
8	The ECG teaching was relevant to my role as a junior doctor.	○	○	○	○	○
9	I was able to understand and retain the ECG interpretation skills taught.	○	○	○	○	○
10	I am satisfied with the quality of ECG interpretation education I received.	○	○	○	○	○
11	I was given enough time and access to resources (e.g., cases, teaching) to learn ECG interpretation properly.	○	○	○	○	○
12	I had enough opportunities to practice interpreting ECGs on real patient cases.	○	○	○	○	○
13	I received useful feedback on my ECG interpretation skills in clinical settings.	○	○	○	○	○

Section 3: Self-Confidence in Interpreting common ECG Patterns.
(tick most appropriate answer)

ECG Pattern	Not at all confident	Slightly confident	Moderately confident	Very confident	Extremely confident
Normal sinus rhythm	○	○	○	○	○
Atrial fibrillation	○	○	○	○	○
ST-elevation myocardial infarction (STEMI)	○	○	○	○	○
Non-ST elevation MI (NSTEMI) changes	○	○	○	○	○
Bundle branch block	○	○	○	○	○
T wave abnormalities	○	○	○	○	○
Ventricular tachycardia	○	○	○	○	○

Section 4: Learning Resources

a) Which of the following did you use for learning ECG interpretation during medical school? (Circle all that apply)
- Textbooks (please specify title): _____
- Online courses (please specify): _____
- Mobile apps (please specify): _____
- In-person formal teaching
- YouTube or other video platforms
- Guidance from senior colleagues/mentors
- Practice on real patient ECGs
- Other (please specify): _____

b) Which resource was the most helpful and why?

_____

Section 5: Barriers and Suggestions for Improvement.
(taking time to answer these questions honestly is greatly appreciated and invaluable)

a) Have you ever felt underprepared when asked to interpret an ECG in a clinical setting?
- Yes
- No

b) If yes, please describe that experience:

_____

c) What do you feel were the biggest challenges or barriers to learning ECG interpretation as a medical student?

_____

d) What changes would you recommend to improve ECG teaching for medical students? _____

_____

e) Would you be interested in more structured ECG teaching during your current training?
- Yes
- No
- Maybe

f) If yes or maybe, which formats would you prefer? (Select all that apply)
- Small group teaching
- Online interactive courses
- Simulation or case-based learning
- Regular bedside teaching
- Mobile app-based modules
- Other (please specify): _____

Section 6: Final Comments (Optional).
Please share any additional thoughts or experiences about ECG interpretation training that you feel are important:

_____.

Thank You!

Thank you for completing this survey. Your input is invaluable and will contribute to understanding and improving ECG education for medical students.

Data availability statement

Data is available upon request.

References

[1] Ehsan L, Fealko C, Maharaj D, Huffman C, Behrle N. Pediatric electrocardiogram interpretation improvement and confidence assessment for resident physicians via training skills workshop. Prog Pediatr Cardiol 2024;72.
[2] Crocetti M, Thompson R. Electrocardiogram interpretation skills in pediatric residents. Ann Pediatr Cardiol 2010;3(1):3–7.
[3] Jablonover R, Lundberg E, Zhang Y, Stagnaro-Green A. Competency in electrocardiogram interpretation among graduating medical students. Teach Learn Med 2014;26(3):279–84.
[4] Eslava D, Dhillon S, Berger J, Homel P, Bergmann S. Interpretation of electrocardiograms by first-year residents: the need for change. J Electrocardiol 2009;42(6):693–7.
[5] Joseph R, Fenton J, Winchester D. Integrated ECG interpretation course for the improvement of medical student electrocardiography literacy. Med Sci Educ 2022; 32(6):1351–4.
[6] Khan J, Ather NA, Niazi G, Khattak M, Razzaq K. Improvement in competency and confidence level of house officers in ECG interpretation after a goal-directed ECG workshop. Pak Armed Forces Med J 2023;73(1):46–9.
[7] Lever N, Larsen P, Dawes M, Wong A, Harding S. Are our medical graduates in New Zealand safe and accurate in ECG interpretation? N Z Med J 2009;122(1292):9–15.

[8] Kodra A, Rambhatla T, Patel S, Coplan N. Assessing the competency of internal medicine residents in electrocardiogram interpretation. Int J Cardiol 2016;214:288–90.
[9] Kashou A, Noseworthy P, Beckman T, Anavekar N, Cullen M, Angstman K, et al. ECG interpretation proficiency of healthcare professionals. Curr Probl Cardiol 2023;48(10):101924.
[10] McAloon C, Leach H, Gill S, Aluwalia A, Trevelyan J. Improving ECG competence in medical trainees in a UK District general hospital. Cardiol Res 2014;5(2):51–7.
[11] Little B, Mainie I, Ho KJ, Scott L. Electrocardiogram and rhythm strip interpretation by final year medical students. Ulster Med J 2001;70(2):108–10.
[12] Vishnevsky G, Cohen T, Elitzur Y, Reis S. Competency and confidence in ECG interpretation among medical students. Int J Med Educ 2022;13:315–21.
[13] Al Mousa A, Alhubail F, Almulhim M, Albeladi B, Almulhim N, Almulhim A, et al. Electrocardiogram interpretation competency of medical interns in Saudi Arabia: a cross-sectional study. Cureus 2023;15(4):e37557.
[14] Kopeć G, Magoń W, Hołda M, Podolec P. Competency in ECG interpretation among medical students. Med Sci Monit 2015;21:3386–94.
[15] Amini K, Mirzaei A, Hosseini M, Zandian H, Azizpour I, Haghi Y. Assessment of electrocardiogram interpretation competency among healthcare professionals and students of Ardabil University of Medical Sciences: a multidisciplinary study. BMC Med Educ 2022;22(1):448.
[16] Getachew M, Beyene T, Kebede S. Electrocardiography interpretation competency of medical interns: experience from two Ethiopian medical schools. Emerg Med Int 2020;2020:7695638.
[17] de Jager J, Wallis L, Maritz D. ECG interpretation skills of south African emergency medicine residents. Int J Emerg Med 2010;3(4):309–14.
[18] Snyder C, Bricker J, Fenrich A, Friedman R, Rosenthal G, Johnsrude C, et al. Can pediatric residents interpret electrocardiograms? Pediatr Cardiol 2005;26(4):396–9.
[19] Cook D, Oh S, Pusic M. Accuracy of physicians' electrocardiogram interpretations: a systematic review and Meta-analysis. JAMA Intern Med 2020;180(11):1461–71.
[20] Hoyle RJ, Walker KJ, Thomson G, Bailey M. Accuracy of electrocardiogram interpretation improves with emergency medicine training. Emerg Med Australas 2007;19(2):143–50.
[21] Cruz MF, Edwards J, Dinh MM, Barnes EH. The effect of clinical history on accuracy of electrocardiograph interpretation among doctors working in emergency departments. Med J Aust 2012;197(3):161–5.
[22] Rakab A, Swed S, Alibrahim H, Bohsas H, Abouainain Y, Abbas KS, et al. Assessment of the competence in electrocardiographic interpretation among Arabic resident doctors at the emergency medicine and internal medicine departments: a multi-center online cross-sectional study. Front Med (Lausanne) 2023;10:1140806.
[23] Raupach T, Hanneforth N, Anders S, Pukrop T, Th Jten Cate O, Harendza S. Impact of teaching and assessment format on electrocardiogram interpretation skills. Med Educ 2010;44(7):731–40.
[24] Ohn M, Souza U, Ohn K. A qualitative study on negative attitude toward electrocardiogram learning among undergraduate medical students. Tzu Chi Med J 2020;32(4):392–7.
[25] O'Cathain A, Murphy E, Nicholl J. The quality of mixed methods studies in health services research. J Health Serv Res Policy 2008;13(2):92–8.
[26] Althubaiti A. Sample size determination: a practical guide for health researchers. J Gen Fam Med 2022;24(2):72–8.
[27] Miles S, Swift L, Leinster SJ. The Dundee ready education environment measure (DREEM): a review of its adoption and use. Med Teach 2012;34(9):e620–34.
[28] Marsh HW. Students' evaluations of university teaching: dimensionality, reliability, validity, potential biases, and utility. J Educ Psychol 1984;76(5):707–54.
[29] Chaumont C, Morgat C, Ollitrault P, Brejoux C, Extramiana F, Milliez P, et al. How to improve medical students' ECG interpretation skills ? Multicenter survey and results of a comparative study evaluating a new educational approach. BMC Med Educ 2024;24(1):979.
[30] Pollock A, O'Sullivan J, Traynor B, Vaughan C. The impact of two hours of electrocardiogram teaching on knowledge and confidence. Int J Integr Med Res 2022;9(3):52–6.
[31] Braun V, Clarke V. Using thematic analysis in psychology. Qual Res Psychol 2006;3(2):77–101.
[32] Nowell LS, Norris JM, White DE, Moules NJ. Thematic analysis: striving to meet the trustworthiness criteria. Int J Qual Methods 2017;16(1):1–13.
[33] Fetters MD, Curry LA, Creswell JW. Achieving integration in mixed methods designs-principles and practices. Health Serv Res 2013;48(6 Pt 2):2134–56.
[34] Veloski J, Boex JR, Grasberger MJ, Evans A, Wolfson DB. Systematic review of the literature on assessment, feedback and physicians' clinical performance: BEME guide no. 7. Med Teach 2006;28(2):117–28.
[35] Archer JC. State of the science in health professional education: effective feedback. Med Educ 2010;44(1):101–8.