How much structuring is beneficial with regard to examination scores ? A prospective study of three forms of active learning

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How much structuring is beneficial with regard to examination scores? A prospective study of three forms of active learning

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Reinhardt CH, Rosen EN. How much structuring is beneficial with regard to examination scores? A prospective study of three forms of active learning. *Adv Physiol Educ* 36: 207–212, 2012; doi:10.1152/advan.00108.2011.—Many studies have demonstrated a superiority of active learning forms compared with traditional lecture. However, there is still debate as to what degree structuring is necessary with regard to high exam outcomes. Seventy-five students from a premedical school were randomly attributed to an active lecture group, a cooperative group, or a collaborative learning group. The active lecture group received lectures with questions to resolve at the end of the lecture. At the same time, the cooperative group and the collaborative group had to work on a problem and prepare presentations for their answers. The collaborative group worked in a mostly self-directed manner; the cooperative group had to follow a time schedule. For the additional work of preparing the poster presentation, the collaborative and cooperative groups were allowed 50% more working time. In *part 1*, all groups worked on the citric acid cycle, and *in part 2*, all groups worked on molecular genetics. Collaborative groups had to work on tasks and prepare presentations for their answers. At the end of each part, all three groups were subjected to the same exam. Additionally, in the collaborative and cooperative groups, the presentations were marked. All evaluations were performed by two independent examiners. Exam results of the active lecture groups were highest. Results of the cooperative group were nonsignificantly lower than the active lecture group and significantly higher than the collaborative group. The presentation quality was nonsignificantly higher in the collaborative group compared with the cooperative group. This study shows that active lecturing produced the highest exam results, which significantly differed from collaborative learning results. The additional elaboration in the cooperative and collaborative learning setting yielded the high presentation quality but apparently could not contribute further to exam scores. Cooperative learning seems to be a good compromise if high exam and presentation scores are expected.

active learning; cooperative learning; collaborative learning; active lecture; exam scores

MANY STUDIES HAVE INDICATED that active forms of learning are more effective than traditional lecture, which is considered as a more passive form of learning (1, 4, 6, 7, 9, 10, 13, 14, 16, 18, 19, 25). In particular, the advantages of active learning forms with regard to conceptual understanding have been emphasized (1, 4, 24, 25). Moreover, active learning forms, especially cooperative ones, have been associated with numerous additional positive effects. Some of these desirable effects are increased student engagement (1, 16, 25), elevated self-belief (16, 25), and improved self-perceived competence (16, 25). Improvement of these factors does not only help students to feel significantly better compared with teacher-centred approaches (1, 16, 18, 26) but are also important factors for success regarding examinations and qualifications (14). Moreover, cooperative learning forms can help to create and ameliorate relationships between students and teachers (6, 25) and also train social skills (3, 4, 16, 17, 25).

However, with regard to exam scores, not all studies support this positive view (2, 11, 12, 20, 26). Many potential reasons for these results have been discussed, and some authors have argued that some studies did not respect standards for "high-quality cooperative learning" (9, 25, 26). It seems to be important that learning is self-directed (4, 8, 25), learners are motivated (6, 8, 9, 25, 26), learners are mutually dependent (18, 25), learners take responsibility for their learning (9, 24, 26), learners are experienced with cooperative learning forms (11, 26), and learners are allowed sufficient time (6, 18, 25).

In the present study, we wanted to examine to what extent structuring is beneficial in active learning forms. Our study continues the research of Banerjee (2), who compared traditional lecture to cooperative learning forms, and Harskamp and Ning Ding (11), who tried to explore what extent of structuring of the collaborative process is needed. In their study (11), they compared a group that solved problems individually with a group that was provided additionally with hints to structure their problem-solving process. This study showed only minor advantages for collaborative learning with hints.

In view of these results, we enlarged the scale comparing learners with very little structuring (collaborative learning) with intermediate structuring (cooperative learning) and high structuring (active lecture). Collaborative learning and cooperative learning are often used interchangeably; in this article, we refer to the definition of Ventamiglia (27), which points out that cooperative learning groups rely on the teacher to organize learning activities and provide sources and that collaborative groups create their own direction and sources.

As mentioned above, for this study, we tried to respect the "standards of quality" for collaborative/cooperative learning stated above: all participants had 6 mo of experience in collaborative and cooperative learning. We used challenging problems (9): "counselling ways on how to lose weight using the acid circle" and to "identify a murderer by means of Southern blot analysis." The collaborative and cooperative learning groups had to exhibit their results by a poster presentation. This multipurpose task (research, poster design, and presentation) was intended to create a setting where learners could contribute their different talents and therefore be mutually dependent. Each learner had to document his/her contributions in a miniportfolio to enhance responsibility for the

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learning process. The collaborative group was free to organize their learning activity with regard to the multipurpose task; the cooperative group was free to determine their learning but had to follow a stricter time schedule with different subtasks.

Following the advice of several authors to provide sufficient learning time for collaborative and cooperative learning (6, 17, 18, 25, 26), the collaborative and cooperative groups were allowed 50% more learning time for performing their extra task.

The degree of structuring as well as the respect of the standards of collaborative and cooperative learning differ in the three arms of this study (active lecture, cooperative learning, and collaborative learning): active lecture is very structured and respects, to a smaller extent, the standards of collaborative and cooperative learning (especially with respect to self-direction); the cooperative learning takes a middle position; and, finally, the collaborative learning is less structured and respects most of the standards.

The aim of this study was to compare the relative effectiveness of three different active learning forms (collaborative learning, cooperative learning, and active lecture) on achievement in physiology at a further education college. The primary outcome parameter was cognitive achievement with regard to a written class test.

The second outcome parameter, which applied only to the collaborative and cooperative groups, was the quality of their poster presentations.

Our hypothesis was that if we respect the standards of collaborative and cooperative learning as described in the literature (6, 8, 9, 18, 25, 26) and provide sufficient learning time (6, 17, 18, 25, 26), cooperative and especially collaborative learners should produce the highest exam scores.

METHODS

Seventy-five students of three physiology courses (mean age: 20.1 ± 1.3 yr) at further education in college (Bonn, Germany) gave their written consent that they could be filmed and their anonymous test results statistically analyzed. Ethical approval and protocol authorization were given by the college's Institutional Review Board. All students were used to active lectures and cooperative and collaborative work for 6 mo.

All participants passed an entry test (cell biology). Participants were stratified with regard to their scores and then randomly distributed to the three groups so that the different grades were equally distributed in each group and the mean score (based on the entry test) was the same in all three groups. All three groups worked on the same two contents, used the same textbook (21), and were taught by the same teacher.

The contents in *part 1* were the "citric acid cycle" and in *part 2* "DNA fingerprinting" (Fig. 1). The active lecture group covered these topics only; the collaborative and cooperative groups were assigned to design posters that answered the tasks with regard to *parts 1* and *2*. In *part 1*, their task was whether sprinting or jogging was more beneficial for losing weight. The answer to this question was to be based on the

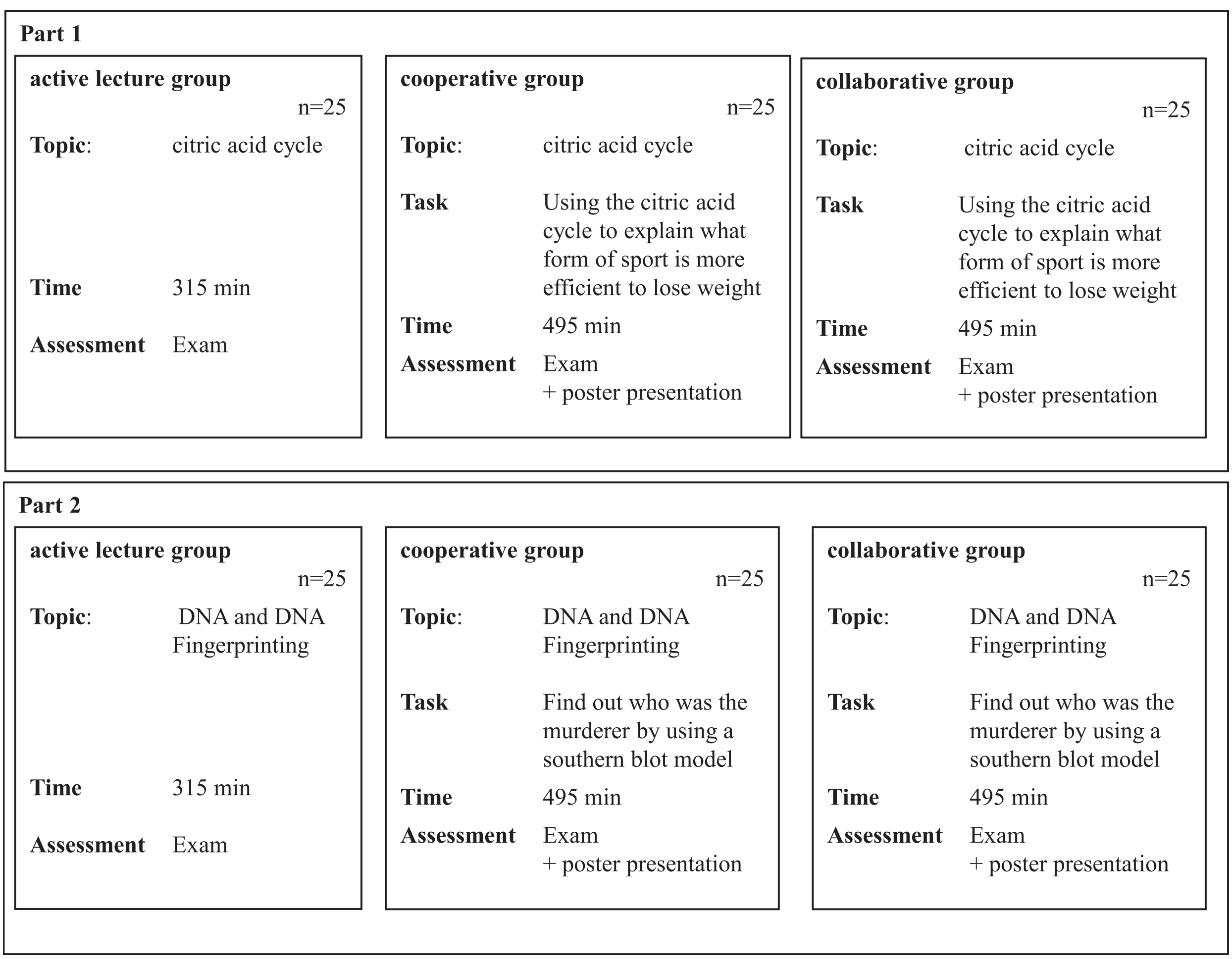

Fig. 1. Flowchart describing *parts 1* and *2*.

citric acid cycle. In *part 2*, their task was to find out who was a murderer 20 yr ago. The answer to this question was to be based on DNA fingerprinting.

As described in the Introduction, the learning time for the active lecture group and the collaborative and cooperative learning groups was different. Because of their additional work load (i.e., design the appropriate poster and preparation for presentation), the collaborative and cooperative groups were accorded an additional 180 min, totaling up to 495 min, respectively, to accomplish their tasks in *parts 1* and *2*. The lecture group was accorded 315 min, respectively.

All groups were informed that at the end of each part an individual exam had to be passed. Moreover they were given an information sheet with general information regarding the topics of the test. A sample question for each level of taxonomy as well as a sample solution was provided.

Active Lecture Group

The active lecture group received several lectures regarding the course subjects. About 15 min of each lecture were reserved for active teaching forms [think-pair (square)-share, concept test, quick thinks, multiple-choice questions, and minute papers (see Ref. 17)].

Collaborative and Cooperative Groups

Conditions that were identical for the collaborative and cooperative groups are summarized below; the particularities of the collaborative and cooperative approaches are specified in their following subsections.

Students in the collaborative and cooperative learning groups benefited from one short lecture giving a general overview of the topics of *parts 1* and *2*, respectively. The collaborative and cooperative learning groups were then divided into assigned subteams of four members. This team assignment allowed a heterogeneous group composition that assured that each group had one student with high exam scores in the pretest. After the initial lecture, the subteams learned at work stations providing additional text books, dictionaries, a computer with an internet connection, and access to the video material, which was used for the active lecture. Moreover, a teaching staff member was available for specific questions and tutoring. The role of the teacher was confined to giving an overview of the contents, providing the tasks for *parts 1* and *2*, clarifying doubts, and periodic group monitoring and discussion with each group. Both groups were provided a guideline regarding the poster presentation specifying the criteria for marking. All participants of the collaborative and cooperative groups had to document their contribution to the processing of the task on a worksheet called the miniportfolio.

Collaborative learning group. Apart from the restrictions described above, the collaborative group was free to determine their learning process and interim outcome goals independently.

Cooperative learning group. The cooperative learning group was to observe the restrictions mentioned above. They could only determine their learning process; the interim outcome goals and time schedule were teacher centered. The time schedule defined the time allowed for the processing of each subtask (i.e., literature research, preliminary draft of their problem solving, poster design, and preparation of the poster presentation). Moreover, the final 60 min of their working time were reserved for answering questions regarding the contents of *parts 1* and *2*. The tasks were the same that were used for the active lecture group. The tasks had to be answered in a think-pair (square)-share manner.

Assessment Tools

The collaborative work was filmed. Students were used to this procedure because video-based group process analysis was performed extensively before.

The next week, both groups were assigned to take an identical required class test in the hall of the institution on the same day. The content validation of the tests was done by other members of the physiology teaching staff and also by administering the tests to the students of the same course who did not participate in this study. Tests had 40% of items that could assess knowledge, 30% of items that could assess comprehension and application, and 30% of items that could assess synthesis and evaluation. Three sample test items, one item from each test, are provided in the APPENDIX. The test items in the three tests were neither discussed nor solved in the classes before the test. The tests were scored by two independent teachers who were blinded as to which group they were examining based on a scoring key prepared on acceptable answers. The answers for each test item were divided into parts, and partial credit for each part was indicated in the scoring key. A 100–91% score was marked as very good (15–13 points), a 90–81% score was marked as good (12–10 points), a 80–66% score was marked as satisfactory (9–7 points), a 65–51% score was marked as passed (6–4 points), and a <50% score was marked as not satisfactory (3–1 points).

The interexaminer reliability was evaluated for each test by calculating the κ-value.

Posters designed by the collaborative and cooperative teams were marked according to a scoring key, which included the correct presentation of facts (40%), usage and explication of technical terms (15%), presentation in a logical order (research question, methods, results, and discussion, 10%), design quality of the poster (20%), and nonverbal presentation quality (i.e., contact with the audience, gestures, and modulation, 15%). The poster presentations were filmed and were marked by two blinded independent examiners. The interexaminer reliability was assessed for each test by calculating the κ-value.

Statistical Analysis

Statistical analysis was performed with distribution-free methods because parametric assumptions were not met with the sample size used. Comparison of each participant's score in *parts 1* and *2* was performed by a Wilcoxon signed-rank test; comparisons of the active lecture group with the cooperative and collaborative groups and comparisons of the cooperative group with the collaborative group were performed using a Mann-Whitney test. Interexaminer reliability was calculated using the κ-test.

RESULTS

Table 1 shows all marks obtained from the students. Exam scores were the primary outcomes of the active lecture and collaborative groups; poster creation and presentation were the secondary outcome, which was performed by the collaborative groups only.

Table 2 shows statistical comparisons with regard to the different approaches (active lecture, cooperative, and collaborative learning) of *parts 1* and *2*. Table 3 shows a longitudinal comparison of the results of the different approaches (active lecture, cooperative, and collaborative learning).

The main findings regarding the primary outcome parameter were a persistant significant difference with regard to exam scores between the active lecture group compared with the collaborative group in *part 1* ($P = 0.009$) and *part 2* ($P = 0.05$), respectively. Cooperative learning groups scored higher than collaborative groups: in *part 1*, cooperative learning groups obtained significantly better results ($P = 0.05$); in *part 2*, cooperative learning groups attained much better results but did not differ significantly ($P = 0.056$).

Comparison of the active lecture group with the cooperative learning group differed nonsignificantly in *part 1* ($P = 0.36$) and *part 2* ($P = 0.2$), respectively.

Table 1. *Descriptive statistics regarding parts 1 and 2*

Approach	Number	Marks: Minimum	Maximum	Mean (SD)	κ value
Part 1: citric acid cycle					
Active lecture cognitive test	25	3.00	14.00	9.92 (2.78)	0.77
Cooperative cognitive test	25	3.00	13.00	9.2 (2.85)	0.76
Cooperative poster	25	6.00	14.00	10.96 (2.57)	0.73
Collaborative cognitive test	25	3.00	13.00	7.4 (3.46)	0.76
Collaborative poster	25	7.00	15.00	11.64 (1.78)	0.74
Part 2: DNA fingerprinting					
Active lecture cognitive test	25	4.00	14.00	10.68 (2.34)	0.72
Cooperative cognitive test	25	3.00	14.00	9.76 (2.54)	0.74
Cooperative poster	25	7.00	14.00	11.16 (1.7)	0.72
Collaborative cognitive test	25	3.00	14.00	7.9 (3.53)	0.76
Collaborative poster	25	7.00	15.00	11.76 (1.8)	0.73

Concerning high taxonomy tasks (synthesis and evaluation), the cooperative and collaborative groups tended to have better results; however, the differences did not reach significance.

As for the second outcome parameter, the quality of the poster presentation, there was a nonsignificant difference between the collaborative group and cooperative group in *part 1* ($P = 0.149$) and *part 2* ($P = 0.685$), respectively.

Analysis of the longitudinal outcome produced some improvement from *part 1* to *part 2* regardless of the approach. The greatest increase was yielded by the collaborative group from *part 1* to *part 2* ($P = 0.062$). This increase was realized predominately by the greatest-performing third of the group.

Interexaminer reliability was calculated using the κ-test; κ-values ranged from 0.72 to 0.77 for the cognitive tests and from 0.72 to 0.74 for the poster presentations.

DISCUSSION

Our results confirm that active lecture is a powerful learning method (1, 13, 22). Moreover, in agreement with previous studies (2, 11, 12, 20, 26), our results show that if exam scores are considered separately, active lecture seems to have an advantage over collaborative learning forms. These results seem to be perfectly summarized by Richardson's view: "do not dump the didactic lecture; fix it" (22). Moreover, our study confirms that with regard to exam scores, a structured learning environment seems to be beneficial (11).

Table 2. *Comparison between the active lecture, collaborative, and cooperative learning groups*

Approach	Approach	*P* Value
Part 1		
Active lecture cognitive test	Cooperative cognitive test	0.364
Active lecture cognitive test	Collaborative cognitive test	0.009
Cooperative cognitive test	Collaborative cognitive test	0.05
Cooperative poster presentation	Collaborative poster presentation	0.149
Part 2		
Active lecture cognitive test	Cooperative cognitive test	0.198
Active lecture cognitive test	Collaborative cognitive test	0.005
Cooperative cognitive test	Collaborative cognitive test	0.056
Cooperative poster presentation	Collaborative poster presentation	0.197

P values were determined by a Mann-Whitney test.

However, with regard to the special conditions in this study (experienced participants with cooperative and collaborative learning, a challenging problem, a learning environment that encouraged mutual dependence and responsibility of the learners, options for self-directed learning, and finally the 1.5-fold increased learning time), it is astonishing that cooperative and collaborative groups did not perform better. Despite this optimized learning setting for collaborative groups, there was a significant difference between the collaborative and active lecture group in *part 1* ($P = 0.009$) and *part 2* ($P = 0.005$) regarding exam scores. The fact that collaborative groups performed worse is bewildering. Moreover, the great difference between exam scores (7.4 and 7.9 points, respectively) and poster presentation marks (11.64 and 11.76 points, respectively), especially in the collaborative learning group, is stunning. These high results of the poster presentation indicate that the relative low exam scores with collaborative learners seem to be neither due to nonengagement with the task (11, 25), and with regard to the miniportfolio, nor to free riding (9, 25). However, accepting these indicators that collaborative and cooperative participants engaged actively, it seems that the acquisition of further competences, such as communication and collaborative skills, does not seem to have a potential to improve exam scores, at least not for all learners. The analysis of the collaborative learning group shows that in *parts 1* and *2*, high marks (13 and 14 points) were achieved by several (good) learners; however, poor learners realised only low grades (3 and 4 points). This discrepancy is reflected in the high SD of the collaborative learning group. Moreover, the relatively important longitudinal increase in exam scores from *part 1* to *part 2* was mainly realized by the good learners who could ameliorate their grades. Apparently, collaborative learning that

Table 3. *Longitudinal comparison of the active lecture, collaborative, and cooperative learning groups*

Part 1	*Part 2*	*P* Value
Approach		
Active lecture cognitive test	Active lecture cognitive test	0.508
Cooperative cognitive test	Cooperative cognitive test	0.077
Collaborative cognitive test	Collaborative cognitive test	0.062
Cooperative poster	Cooperative poster	0.405
Collaborative poster	Collaborative poster	0.225

P values were determined by a Wilcoxon signed-ranks test.

stresses responsibility (which, in this study, was assured by the miniportfolio, where all participants had to document their contributions) does not push poor learners to laze around but invites them to engage in nonexam-related activities (such as poster design). The failure of students to change their strategies in *part 2* despite their poor results in *part 1* confirms that self-assessment and reflection is a difficult task (15) that cannot be easily achieved by poor learners.

These learners seem to benefit enormously from structuring. The cooperative approach obliged learners to reserve $<15\%$ of their learning time for answering content-related questions. This small investment of time resulted in a significant ($P = 0.05$) difference in exam scores for cooperative learning groups compared with collaborative learning groups in *part 1*; in *part 2*, the difference diminished but remained almost significant ($P = 0.056$). Moreover, this structuring resulted in exam scores that differed nonsignificantly from exam scores of active lecture learners in *part 1* ($P = 0.364$) and *part 2* ($P = 0.198$), respectively. These results convinced us to reject our hypothesis. Our results seem to indicate that structuring should be considered as a key factor with regard to high exam scores.

When we compared the poster presentation results of the collaborative and cooperative groups, the results were almost similar ($P = 0.149$ and 0.197, respectively). Thus, the cooperative group participants could yield a comparable high presentation quality and, at the same time, realized a significant difference in exam scores output, which was almost as high as the exam scores of the lecture group.

Acknowledging that communication and collaborative skills are increasingly recognized as highly important elements of medical expertise (14, 23, 25), the cooperative learning approach appears to be a reasonable compromise if high exam scores and social skills are to be facilitated. If collaborative learning is opted for, it seems worthwhile to propose some form of support for poorer learners. Recent computerized learning tools can provide this individual scaffolding and may therefore provide a good balance of challenge and support for these learners (11).

Limitations

The further education college where the study took place is a premedical school. This implicates that the results of this study should be applicable to preclinical students; however, transfer of these results to clinical students should be done cautiously. The results of this study were gained with a seminar-like sample size. This sample size might tend to overestimate the effect of the active lecture because members of this relatively small group benefited from a closer contact to the lecturer, which would be difficult to realize in a large lecturing theater. On the other hand, the limited number of students enrolled allowed us to review all student production twice by two independent examiners, which is advisable for higher learning tasks and especially for the poster presentation (3). In the present study, we can support our results by a good interexaminer reliability (with κ-values from 0.72 to 0.77).

We cannot completely rule out that the inferior test results of the cooperative and collaborative learning environment might have been due to case studies that were not challenging enough. However, two facts seem to indicate that this should not be a major confounding factor: *1*) these differences were consistent for *parts 1* and *2* of this study and *2*) test results from the cooperative learning environment were considerably higher than those of the collaborative learning environment even though they used the same case study.

Conclusions

The results of this study indicate that an active lecture seems to be superior to a collaborative learning setting if exam scores are examined exclusively and learning time restrictions are considered. Apparently, additional acquisition of communication and collaborative skills do not directly contribute to exam scores. When 1.5-fold the learning time was allowed, the cooperative learning approach yielded a comparable exam score to the active lecture. The more structured cooperative learning approach yielded significantly higher exam scores than the collaborative approach and was especially beneficial for poorer learners. This indicates that structuring the learning time and the introduction of even a small portion of compulsory time for content-related question solving are beneficial, especially for poorer learners, with regard to exam scores.

APPENDIX

Example Exam Questions

Question 1: assessing knowledge. "Name the three parts of a nucleotide."

Question 2: comprehension and application. "Please describe the use of the 'baking' process in the Southern blot procedure."

Question 3: synthesis and evaluation. "On the spot of a murder, a cigarette is found. After thorough a police inquisition, two near relatives (two brothers) are suspected of committing the murder, and their DNA is submitted to a Southern blot. Please describe how it can be assured that the actual murderer is correctly identified."

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

Author contributions: C.H.R. and E.N.R. conception and design of research; C.H.R. performed experiments; C.H.R. analyzed data; C.H.R. drafted manuscript; E.N.R. interpreted results of experiments; E.N.R. edited and revised manuscript.

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