## 5.2.2 : class work problems

① The mean and standard deviation of height of 8 - randomly chosen Soldiers are 166.9 cm and 8.29 cm respectively. ~~Based~~/on this data, ~~can~~ ~~we conclude that~~ The corresponding values of 6 randomly chosen Sailors are 170.3 cm and 8.50 cm respectively. Based on this data, can we conclude that the soldiers are in general shorter than Sailors ? Find the 95% confidence limits for the test statistic used

Solution: By given $n_1 = 8$ $\bar{x}_1 = 166.9$ $S_1 = 8.29$, $n_2 = 6$, $\bar{x}_2 = 170.3$ & $S_2 = 8.50$

$H_0 : \mu_1 = \mu_2$

$H_1 : \mu_1 < \mu_2$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{n_1 S_1^2 + n_2 S_2^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} = \frac{166.9 - 170.3}{\sqrt{\frac{(8 \times 8.29^2) + (6 \times 8.50^2)}{8 + 6 - 2}\left(\frac{1}{8} + \frac{1}{6}\right)}}$$

$t = -0.6955$ $\therefore |t| = 0.6955$

$\nu = n_1 + n_2 - 2 = 8 + 6 - 2 = 12$

$t_\nu(\alpha) = t_{12}(5\%) = 2.179$

$\therefore |t| < t_\nu(\alpha)$ $\therefore H_0$ is accepted ie $\mu_1 = \mu_2$

$\therefore$ we can not conclude that the solider are shorter than Sailors.

② To find out whether a new serum will arrest leukemia, 9 mice all with an advanced stage of disease, are selected. Five mice receive the treatment and four do not. Survival times in years from the time the experiment commences are as follows:-

| | | | | | |
|---|---|---|---|---|---|
| Treatment | 2.1 | 5.3 | 1.4 | 4.6 | 0.9 |
| No. treatment | 1.9 | 0.5 | 2.8 | 3.1 | |

At the 0.05 LOS can the serum be said to be effective ? Assume the two distributions to be normally distribution with equal Variance

Solution: $n_1 = 5$, $n_2 = 4$, $\bar{x}_1 = 2.86$ $\bar{x}_2 = 2.075$ $S_1^2 = \frac{1}{n}\Sigma(x_1)^2 - (\bar{x}_1)^2 = 3.1064$

$\therefore$ $S_1 = 1.7625$ $S_2^2 = \frac{1}{n}\Sigma(x_2)^2 - (\bar{x}_2)^2 = 1.0219$ $S_2 = 1.0109$

$H_0 : \mu_1 = \mu_2$

$H_1 : \mu_1 > \mu_2$, $\nu = \cancel{n_1 + n_2} - 2 = 5 + 4 - 2 = 7$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{n_1 S_1^2 + n_2 S_2^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} = \frac{2.86 - 2.075}{\sqrt{\frac{(5 \times 3.1064) + (4 \times 1.0219)}{5 + 4 - 2}\left(\frac{1}{5} + \frac{1}{4}\right)}}$$

$t = 0.69898$, $t_\nu(\alpha) = t_7(5\%) = \cancel{2.365}$ 1.895, $t < t_\nu(\alpha)$

$\therefore H_0$ is accepted ie $\mu_1 = \mu_2$

We cannot conclude that the serum be said to be effective

③ A Sampe of 8 students of 16 years each shown up a ~~new~~ mean systolic blood pressure of 118.4 mm of Hg with S.D of 12.17mm while a Sample of 10 Student of 17 years each showed the mean systolic BP of 121.0mm with SD of 12.88 mm. during an investigation. The invesgator feels that systelic BP is related to age. Dou you think that the data provides enough reasons to supports investigators feeling at 5% Los? Assume that distribution of systolic BP to be normal

solution: $n_1 = 8$ $\bar{x}_1 = 118.4$, $s_1 = 12.17$, $n_2 = 10$, $\bar{x}_2 = 121.0$ $s_2 = 12.88$

$H_0: \mu_1 = \mu_2$

$H_1: \mu_1 < \mu_2$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{n_1 s_1^2 + n_2 s_2^2}{n_1 + n_2 - 2}\left[\frac{1}{n_1} + \frac{1}{n_2}\right]}} = \frac{118.4 - 121.0}{\sqrt{\frac{(8 \times 12.17^2)(10 \times 12.88^2)}{8 + 10 - 2}\left(\frac{1}{8} + \frac{1}{10}\right)}}$$

$t = -0.4111$ $\therefore |t| = 0.4111$

$\nu = n_1 + n_2 - 2 = 8 + 10 - 2 = 16$

$\therefore t_\nu(\alpha) = t_{16}(5\%) = 1.746$

$\because |t| < t_\nu(\alpha)$ $\therefore H_0$ is accepted ie $\mu_1 = \mu_2$

we can not conclude that "investigator fells that the systolic BP is learated to age

④ Two independent samples of sizes 8 and 7 gave the following results:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sample 1 | 19 | 17 | 15 | 21 | 16 | 18 | 16 | 14 |
| Sample-2 | 15 | 14 | 15 | 19 | 15 | 18 | 16 | — |

Is the difference between sample mean significant

Solution: $n_1 = 8$ $n_2 = 7$, $\bar{x}_1 = 17$ $s_1^2 = 4.5$ $\bar{x}_2 = 16$ $s_2^2 = 2.857143$

$H_0: \bar{x}_1 = \bar{x}_2$

$H_1: \bar{x}_1 = \bar{x}_2$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{n_1 s_1^2 + n_2 s_2^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} = \frac{17 - 16}{\sqrt{\frac{(8 \times 4.5) + (7 \times 2.857143)}{8 + 7 - 2} \times \left(\frac{1}{8} + \frac{1}{7}\right)}} = 0.9309$$

$\nu = n_1 + n_2 - 2 = 13$ $\therefore t_\nu(\alpha\%) = t_{13}(5\%) = 2.160$

$\therefore t < t_\nu(\alpha)$

$\therefore H_0$ is accepted ie $\bar{x}_1 = \bar{x}_2$

$\therefore$ There is no significant difference in two sample mean

⑤ For a random Sample of 10 children fed a diet 'A' the increase in weights was 10, 6, 16, 17, 13, 12, 8, 14, 15, 09, For a random sample of 12 children fed on diet B the increase in weight was 7, 13, 22, 15, 12, 14, 18, 8, 21, 23, 10, 17. Test whether diet A and B differ significantly as regard effect in increase in weight. use 5% LOS

**Solution:** $n_1 = 10$, $n_2 = 12$, $\bar{x}_1 = 12$, $s_1^2 = 12$, $\bar{x}_2 = 15$, $s_2^2 = 26.1667$

$H_0: \bar{x}_1 = \bar{x}_2$

$H_1: \bar{x}_1 \neq \bar{x}_2$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{n_1 s_1^2 + n_2 s_2^2}{n_1+n_2-2}\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}} = \frac{12-15}{\sqrt{\frac{(10\times 12)+(12\times 26.1667)}{10+12-2}\left(\frac{1}{10}+\frac{1}{12}\right)}} = -1.5041$$

$\therefore |t| = 1.5041$

$\nu = n_1 + n_2 - 2 = 20$, $t_\nu(\alpha\%) = t_{20}(5\%) = 2.086$

$\because |t| < t_\nu(\alpha)$ $\therefore$ $H_0$ is accepted ie $\bar{x}_1 = \bar{x}_2$

$\therefore$ we can not say that diet A and B differ significantly as regard effect in increase in weight

## 5.2.2: Home work Problem

① The means of two random samples of size 9 and 7 are 196.42 and 198.82 respectively. The sum of squares of the deviation from the mean are 26.94 and 18.73 respectively. can the samples be considered to have been drawn from the same population?

**Solution:** $n_1 = 9$, $n_2 = 7$, $\bar{x}_1 = 196.42$, $\bar{x}_2 = 198.82$, $s_1^2 = \frac{1}{n_1}\sum(x_1-\bar{x}_1)^2 = \frac{1}{9}(26.94) = 2.9933$

$s_2^2 = \frac{1}{n_2}\sum(x_2-\bar{x}_2)^2 = \frac{1}{7}(18.73) = 2.6757$

$H_0: \mu_1 = \mu_2$

$H_1: \mu_1 \neq \mu_2$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{n_1 s_1^2 + n_2 s_2^2}{n_1+n_2-2}\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}} = \frac{196.42-198.82}{\sqrt{\frac{(9\times 2.9933)+(7\times 2.6757)}{9+7-2}\left(\frac{1}{9}+\frac{1}{7}\right)}} = -2.6368$$

$\therefore |t| = 2.6368$

Now $\nu = n_1 + n_2 - 2 = 14$

$\therefore t_\nu(\alpha) = t_{14}(5\%) = 2.145$

$\therefore |t| > t_\nu(\alpha)$ $\therefore$ $H_0$ is rejected ie $H_1$ is accepted

ie $\mu_1 \neq \mu_2$

we can conclude that the two samples be considered as drawn from the same population

The mean inside diameter of a sample of 500 washers produced by a machine 0.502 cm and the standard deviation is 0.005 cm. The purpose for which these they are intended allows a maximum tolerance in the diameter of 0.496 to 0.508 cm, otherwise the washers are considered defective. Determine the percentage defective washers produced by the machine, assuming the diameter are normally distributed.

Solution: By given $\mu = 0.502$ $\sigma = 0.005$.

Now $P(0.496 < x < 0.508) = P\left(\frac{0.496-\mu}{\sigma} < \frac{x-\mu}{\sigma} < \frac{0.508-\mu}{\sigma}\right)$

$= P\left(\frac{0.496-0.502}{0.005} < z < \frac{0.508-0.502}{0.005}\right) = P(-1.2 < z < 1.2)$

$= 2P(0 < z < 1.2) = 2 \times 0.3849 = 0.7698$ gives probability of accepting washer

Probability of rejecting washers $= 1 - 0.7698 = 0.2302$

Percentage of defective ~~wishers~~ a washers produced by machine $= 0.2302$

Expected number of defective washers produced by machine $= 46.04 \approx 46$

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The following data represent the biological value of protein from cow's milk and buffaloes milk at a certain level

| | | | | | | |
|---|---|---|---|---|---|---|
| Cow's milk | 1.82 | 2.02 | 1.88 | 1.61 | 1.81 | 1.54 |
| Buffaloes milk | 2.00 | 1.83 | 1.86 | 2.03 | 2.19 | 1.88 |

Examine if the average value of protein in two samples differ significantly.

Solution: $n_1 = n_2 = 6$, $\bar{x}_1 = 1.78$ $s_1^2 = 0.0261$ $\bar{x}_2 = 1.965$ $s_2^2 = 0.015425$

$H_0$: $\mu_1 = \mu_2$

$H_1$: $\mu_1 \neq \mu_2$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2 + s_2^2}{n-1}}} = \frac{1.78 - 1.965}{\sqrt{\frac{0.0261 + 0.015425}{5}}} = -2.03$$

$\therefore |t| = 2.03$

$v = 2(n-1) = 2 \times 5 = 10$

$\therefore t_v(\alpha) = t_{10}(5\%) = 2.228$

$\because |t| < t_v(\alpha)$ $\therefore H_0$ is accepted i.e. $\mu_1 = \mu_2$

$\therefore$ We can not conclude that the average value of protein in two samples differ significantly

## 5:2.3: class work Problems

① On a certain day a group of 7 guinea pigs were injected with 0.5 mg of a tranquiliser and the following number of seconds were required by them to fall asleep 8.2, 10.2, 10.0, 14.0, 13.7, 10.9, 7.8. on the following day each pig was injected with 1.0 mg of the same tranquiliser and the time taken by them to fall asleep (in second) was recorded as 9.7, 7.5, 9.3, 13.2, 14.0, 10.1 & 8.0 respectively. Do the data indicate that there is a real difference in the time taken to fall asleep due to difference in dosage at 1%. LOS

**Solution**: $n=7$

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $x$ | 8.2 | 10.2 | 10.0 | 14.0 | 13.7 | 10.9 | 7.8 | |
| $y$ | 9.7 | 7.5 | 9.3 | 13.2 | 14.0 | 10.1 | 8.0 | |
| $d_i = x_i - y_i$ | -1.5 | 2.7 | 0.7 | 0.8 | -0.3 | 0.8 | -0.2 | $\Sigma d_i = 3$, $\bar{d} = 3/7$ |
| $d_i^2 =$ | 2.25 | 7.29 | 0.49 | 0.64 | 0.09 | 0.64 | 0.04 | $\Sigma(d_i)^2 = 11.44$ ∴ $S_d^2 = 1.4506$ ∴ $S_d = 1.2044$ |

$H_0: \bar{d} = 0$ (ie $\bar{x} = \bar{y}$)

$H_1: \bar{d} \neq 0$ (ie, $\bar{x} \neq \bar{y}$)

$\therefore t = \frac{\bar{d} - 0}{S_d/\sqrt{n-1}} = \frac{3/7}{1.2044/\sqrt{6}} = 0.8716$, $\nu = n-1 = 6$, $t_\nu(\alpha) = t_6(1\%) = 3.707$

$\therefore t < t_\nu(\alpha)$ ∴ Ho is accepted ie $\bar{d} = 0$ ie $\bar{x} = \bar{y}$

we conclude that there is no real difference in the time taken to fall asleep due to difference in the dosage

② A certain injection administered to each of the 12 patients resulted in the following increase of blood pressure: 5, 2, 8, -1, 3, 0, 6, -2, 1, 5, 0, 4. Can it be conclude that the injection will be in general accompanied by an increase in blood pressure?

**Solution**:

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $d_i =$ | 5 | 2 | 8 | -1 | 3 | 0 | 6 | -2 | 1 | 5 | 0 | 4 | $\Sigma d_i = 31$ |
| $(d_i)^2 =$ | 25 | 4 | 64 | 1 | 9 | 0 | 36 | 4 | 1 | 25 | 0 | 16 | $\Sigma(d_i)^2 = 185$ |

$\bar{d} = 2.5833$, ∴ $S_d^2 = 8.7431$ ∴ $S_d = 2.9569$

$H_0: \bar{d} = 0$

$H_1: \bar{d} < 0$

$t = \frac{\bar{d} - 0}{S_d/\sqrt{n-1}} = \frac{2.5833 - 0}{2.9569/\sqrt{11}} = 2.8976$ $

$N = n-1 = 11$ ∴ $t_\nu(\alpha) = t_{11}(5\%) = 2.201$

$\therefore t > t_\nu(\alpha)$

∴ Ho is rejected ie $H_1$ is accepted ie $\bar{d} < 0$

∴ we came conclude that the injected will be in general accompanied by an increase in blood pressure

③ In a certain experiment to compare two types of pig foods. A and B the following results of increasing weights were observed in pigs

| Pig number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| increase in weight x kg in food A(x) | 49 | 53 | 51 | 52 | 47 | 50 | 52 | 53 |
| increase in weight y kg in food B(y) | 52 | 55 | 52 | 53 | 50 | 54 | 54 | 53 |

① Assuming that the two sample of pigs are independent, can we conclude that food B is better than food A

② Examine the case if the same set of 8 pigs were used in both cases.

Solution

Case 1

$n_1 = n_2 = 8$, $\overline{x_1} = 50.875$ $s_1^2 = 3.859375$

$\overline{x_2} = 52.875$ $s_2^2 = 2.109375$

$H_0: \mu_1 = \mu_2$

$H_1: \mu_1 < \mu_2$

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{s_1^2 + s_2^2}{n_1}}} = \frac{50.875 - 52.875}{\sqrt{\frac{3.859375 + 2.109375}{7}}} = -1.3368$$

$\therefore |t| = 1.3368$, $\nu = 2(n-1) = 2 \times 7 = 14$

$\therefore t_\nu(\alpha) = t_{14}(5\%) = 1.761$

$\because |t| < t_\nu(\alpha)$ $\therefore$ $H_0$ is accepted ie $\mu_1 = \mu_2$

$\therefore$ we can not conclude that food B is better than food A

Case - 2

| $d_i = x_1 - x_2$ | -3 | -2 | -1 | -1 | -3 | -4 | -2 | 0 | $\Sigma d_i = -16$ |
|---|---|---|---|---|---|---|---|---|---|
| $(d_i)^2$ | 9 | 4 | 1 | 1 | 9 | 16 | 4 | 0 | $\Sigma(d_i)^2 = 44$ |

$\therefore \bar{d} = -2$ $\therefore s^2 = 1.5$ $\therefore s = 1.224744871$

$H_0: \bar{d} = 0$ $(\overline{x_1} = \overline{x_2})$

$H_1: \bar{d} < 0$ $(\overline{x_1} < \overline{x_2})$

$$t = \frac{\bar{d} - 0}{s/\sqrt{n-1}} = \frac{-2}{1.224744871/\sqrt{7}} = 4.3205$$

$\nu = n - 1 = 7$ $\therefore t_\nu(\alpha) = t_7(5\%) = 1.895$

$\therefore t > t_\nu(\alpha)$ $H_0$ is rejected ie $H_1$ is accepted ie $\bar{d} < 0$ ie $\overline{x_1} < \overline{x_2}$

$\therefore$ we can conclude that food B is better than food A

(4) A drug is administered to 5 persons and the systolic blood pressure before and after was measured. The results are given below:

| Candidate | I | II | III | IV | V |
|---|---|---|---|---|---|
| B.P. before | 140 | 130 | 132 | 150 | 140 |
| B.P. after | 132 | 126 | 133 | 144 | 133 |

Test whether the drug is effective in lowering the systolic blood pressure at 5% LOS

Solution

| B.P. before ($x$) | 140 | 130 | 132 | 150 | 140 |
|---|---|---|---|---|---|
| B.P. after ($y$) | 132 | 126 | 133 | 144 | 133 |
| $d_i = x_i - y_i$ | -8 | -4 | 1 | -6 | -7 |
| $(d_i)^2$ | 64 | 16 | 1 | 36 | 49 |

$\bar{d} = \frac{1}{n}\Sigma(d_i) = \frac{-24}{5} = -4.8$, $s^2 = 10.16$ $\therefore s = 3.1875$, $n = 5$

$H_0 : \bar{d} = 0$, $(\bar{x} = \bar{y})$

$H_1 : \bar{d} < 0$, $(\bar{x} < \bar{y})$

$\therefore t = \cancel{\frac{\bar{x}-\mu}{s/\sqrt{n_1}}} = \frac{\bar{d}-0}{s/\sqrt{n_1}} = \frac{-4.8-0}{3.1875/\sqrt{4}} = -3.011765$

$\therefore |t| = 3.011765$ $\nu = n-1 = 4$ $t_\nu(\alpha) = t_4(5\%) = 2.132$

Thus $|t| > t_\nu(\alpha)$ $\therefore H_0$ is rejected ie $H_1$ is accepted ie $\bar{d} < 0$

$\therefore$ we can conclude that drug is effective in lowering blood pressure

## 5.2.3 : Home work Problems

(1) The following data relates to the marks obtained by 11 students in two tests, one held at the beginning of the year and the other at the end of the year after giving intensive coaching. Do the data indicate the students are benefited by coaching?

Data:

| Test-1 $x$ | 19 | 23 | 16 | 24 | 17 | 18 | 20 | 18 | 21 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Test-2 $y$ | 17 | 24 | 20 | 24 | 20 | 22 | 20 | 20 | 18 | 22 | 18 |
| $d_i = x - y$ | -2 | 1 | 4 | 0 | 3 | 4 | 0 | 2 | -3 | 3 | -2 |
| $d_i^2$ | 4 | 1 | 16 | 0 | 9 | 16 | 0 | 4 | 9 | 9 | 4 |

$\bar{d} = \cancel{\frac{1}{10}} \frac{1}{n}\Sigma d_i = \frac{10}{11} = 0.9091$

$s^2 = \frac{1}{n}\Sigma(d_i)^2 - (\bar{d})^2 = \frac{72}{11} - (0.9091)^2 = 5.718992$, $s = 2.391441$

$H_0 : \bar{d} = 0$ $(\bar{x} = \bar{y})$

$H_1 : \bar{d} < 0$ $(\bar{x} < \bar{y})$

$t = \frac{\bar{d}-0}{s/\sqrt{n_1}} = \frac{0.9091}{2.391441/\sqrt{10}} = 1.2021$

$\nu = n-1 = 10$, $t_\nu(\alpha) = \cancel{t_5(5\%)} = t_{10}(5\%) = 1.812$

$\therefore |t| < t_\nu(\alpha)$ $\therefore H_0$ is accepted ie $\bar{d} = 0$ ie $\bar{x} = \bar{y}$

we can not conclude that the students are benefited by coaching

(3) An I.Q. test was administrated to 5 persons and after they were trained results are given below. Test whether there is any change in I.Q. after the training programming use 1% LoS.

Data

| | I | II | III | IV | V | |
|---|---|---|---|---|---|---|
| I.Q. before training ($x$) | 110 | 120 | 123 | 132 | 125 | |
| I.Q. after training ($y$) | 120 | 118 | 125 | 136 | 121 | |
| $d_i = x_i - y_i$ | 10 | -2 | 2 | 4 | -4 | $\Sigma d_i = 10$ |
| $(d_i)^2$ | 100 | 4 | 4 | 16 | 16 | $\Sigma d_i^2 = 140$ |

$\bar{d} = \frac{1}{n}\Sigma d_i = \frac{1}{5}\cdot 10 = 2$, $s = \frac{1}{n}\Sigma(d_i)^2 - (\bar{d})^2 = \frac{140}{5} - (2)^2 = 28 - 4 = 24$

$H_0 : \bar{d} = 0$ $(\bar{x} = \bar{y})$

$H_1 : \bar{d} \neq 0$ $(\bar{x} \neq \bar{y})$

$t = \frac{\bar{d} - 0}{s/\sqrt{n-1}} = \frac{2-0}{24/\sqrt{4}} = 0.1667$

$\nu = n-1 = 4$, $t_\nu(\alpha) = t_4(1\%) = 4.604$

$\because t < t_\nu(\alpha)$ $\therefore H_0$ is accepted ie $\bar{d} = 0$ ie $\bar{x} = \bar{y}$

There is no any change in I.Q. after training

(3) The following data represent the marks obtained by 12 students in 2 tests one held before coaching and one held after coaching. Does the data indicate that the coaching was effective in improving the performance of the students

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test 1 ($x$) | 55 | 60 | 65 | 75 | 49 | 25 | 18 | 30 | 35 | 54 | 61 | 72 | |
| Test-2 ($y$) | 63 | 70 | 70 | 81 | 54 | 29 | 21 | 28 | 32 | 50 | 70 | 80 | |
| $d_i = x_i - y_i$ | 8 | 10 | 5 | 6 | 5 | 4 | 3 | -2 | -3 | -4 | 9 | 8 | $\Sigma d_i = 49$ |
| $(d_i)^2$ | 64 | 100 | 25 | 36 | 25 | 16 | 9 | 4 | 9 | 16 | 81 | 64 | $\Sigma(d_i)^2 = 449$ |

$\therefore \bar{d} = \frac{1}{n}\Sigma d_i = 4.0833$ $\therefore s^2 = 20.7431$ $s = 4.5545$

$H_0 : \bar{d} = 0$ $(\bar{x} = \bar{y})$

$H_1 : \bar{d} < 0$ $(\bar{x} < \bar{y})$

$t = \frac{\bar{d} - 0}{s/\sqrt{n-1}} = \frac{4.0833}{4.5545/\sqrt{11}} = 2.9735$

$\nu = n-1 = 11$ $\therefore t_\nu(\alpha) = t_{11}(5\%) = 1.796$

$\therefore |t| > t_\nu(\alpha)$ $\therefore H_0$ is rejected ie $H_1$ is accepted

$\therefore \bar{d} < 0$ ie $\bar{x} < \bar{y}$

$\therefore$ data indicate that the coaching was effective in improving the performance of the students