Dilemma:

$$(a)\ \ E[g(y|x)] = \sum g(y|x)\, p(y|x)$$

- Or -

$$(b)\ \ E[g(y|x)] = \sum g(y|x)\, p(y,x)$$

Assert that (b) is correct.

Proof:

The definition of the expectation of a random variable g(X) is

$$E_p g(X) = \sum_{x \in X} g(x) p(x)$$

And can be generalized to two a distribution of two random variables, for example, when used to express joint entropy:

$$H(X,Y) = -\sum_{x \in X} \sum_{y \in Y} p(x,y) \log p(x,y) = -E \log p(X,Y)$$

Here, g(x) has been replaced by g(x,y) = log p(x,y).

If instead we let g(x,y) = g(y|x) = log p(y|x) as with conditional entropy, we arrive at

$$H(Y|X) = -\sum_{x \in X} \sum_{y \in Y} p(x,y) \log p(Y|X) = -E \log p(Y|X)$$

Which clearly follows (b)